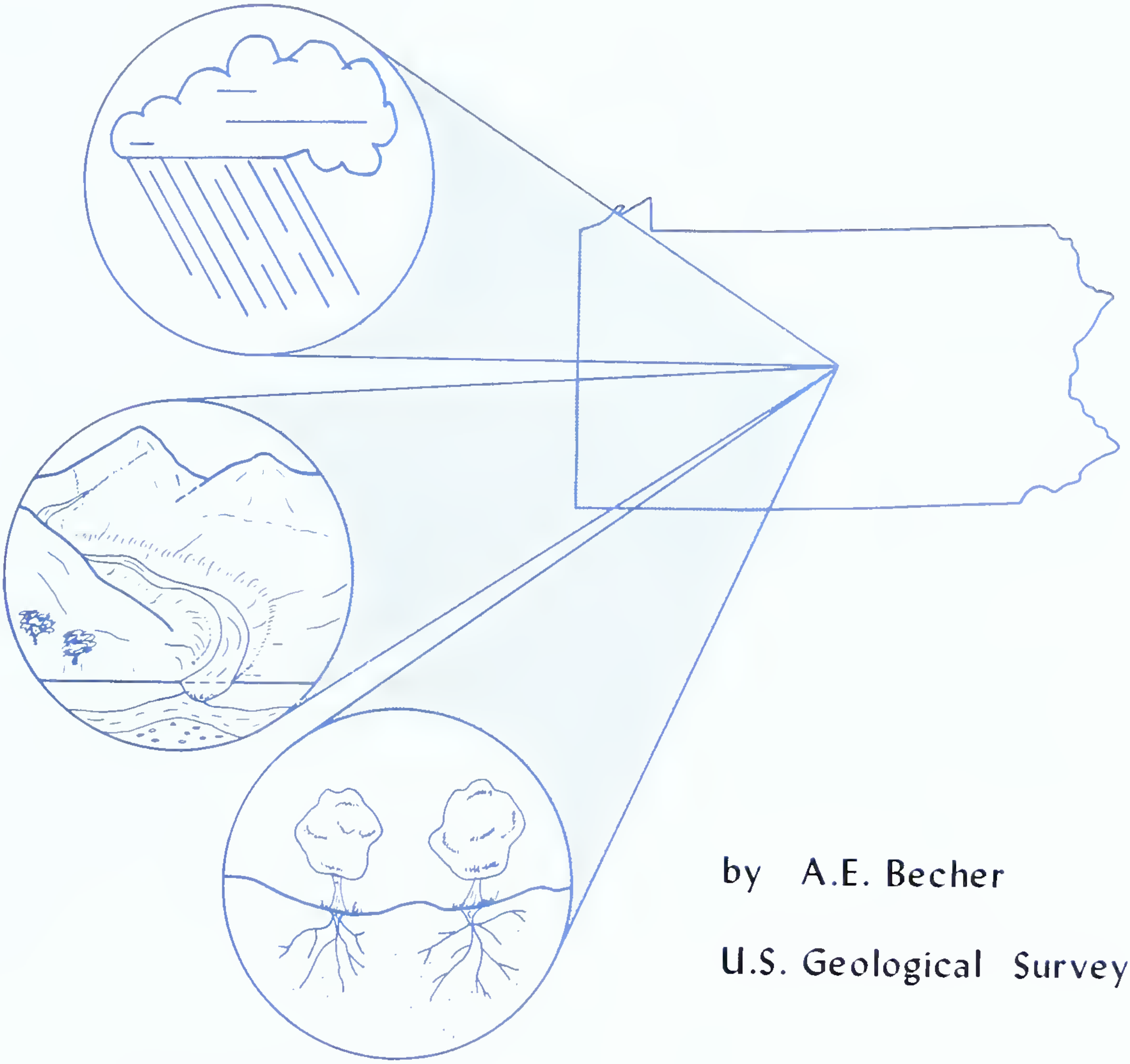
Ground water in Pennsylvania

GROUND WATER IN PENNSYLVANIA

PENNSYLVANIA GEOLOGIC SURVEY

EDUCATIONAL SERIES NO. 3

Ground Water in Pennsylvania



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U.S. Geological Survey

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF
ENVIRONMENTAL RESOURCES
BUREAU OF
TOPOGRAPHIC AND GEOLOGIC SURVEY
Arthur A. Socolow, State Geologist

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PREFACE

This publication is presented in recognition of Pennsylvania's growing need for water as well as from a widespread awareness that the quality of our water must be preserved even as the use of our waters must be wisely managed.

Ground water, that portion of our water resources which is located in the rocks beneath the surface of the earth, is an important part of our water resources which is still largely underdeveloped in Pennsylvania. Its importance is enhanced by the fact that ground-water resources are less prone than surface waters to be affected by droughts or conditions of surficial and atmospheric pollution.

This publication presents the principles of ground-water occurrence and movements, the mechanics of effective ground-water development through wells, and a summarization of ground-water availability throughout the commonwealth. It is hoped that the reader will thus better appreciate the importance of this most valuable resource of Pennsylvania, so that he in turn can contribute to the conservation and wise use of our ground water.

Arthur A. Socolow

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GROUND WATER IN PENNSYLVANIA

by

A. E. Becher

U. S. Geological Survey

INTRODUCTION

Pennsylvania is blessed with abundant water resources. Despite this abundance, water problems exist and many more will surely arise in the future. These problems result partly from imbalances between the natural distribution of water in space and time and the distribution that we desire, as well as from the polluting effects of nature and man's activities.

To solve water problems and to make intelligent decisions about developing water supplies require a knowledge of basic principles as well as certain fundamental data.

This report summarizes the existing knowledge of the ground-water resources of Pennsylvania. It is written to provide industrial and civil planners, developers, managers, and the public with sufficient information about statewide water resources, particularly ground-water resources, to make intelligent, fundamental decisions about the future use, development, and protection of our ground water.

PENNSYLVANIA IN PERSPECTIVE

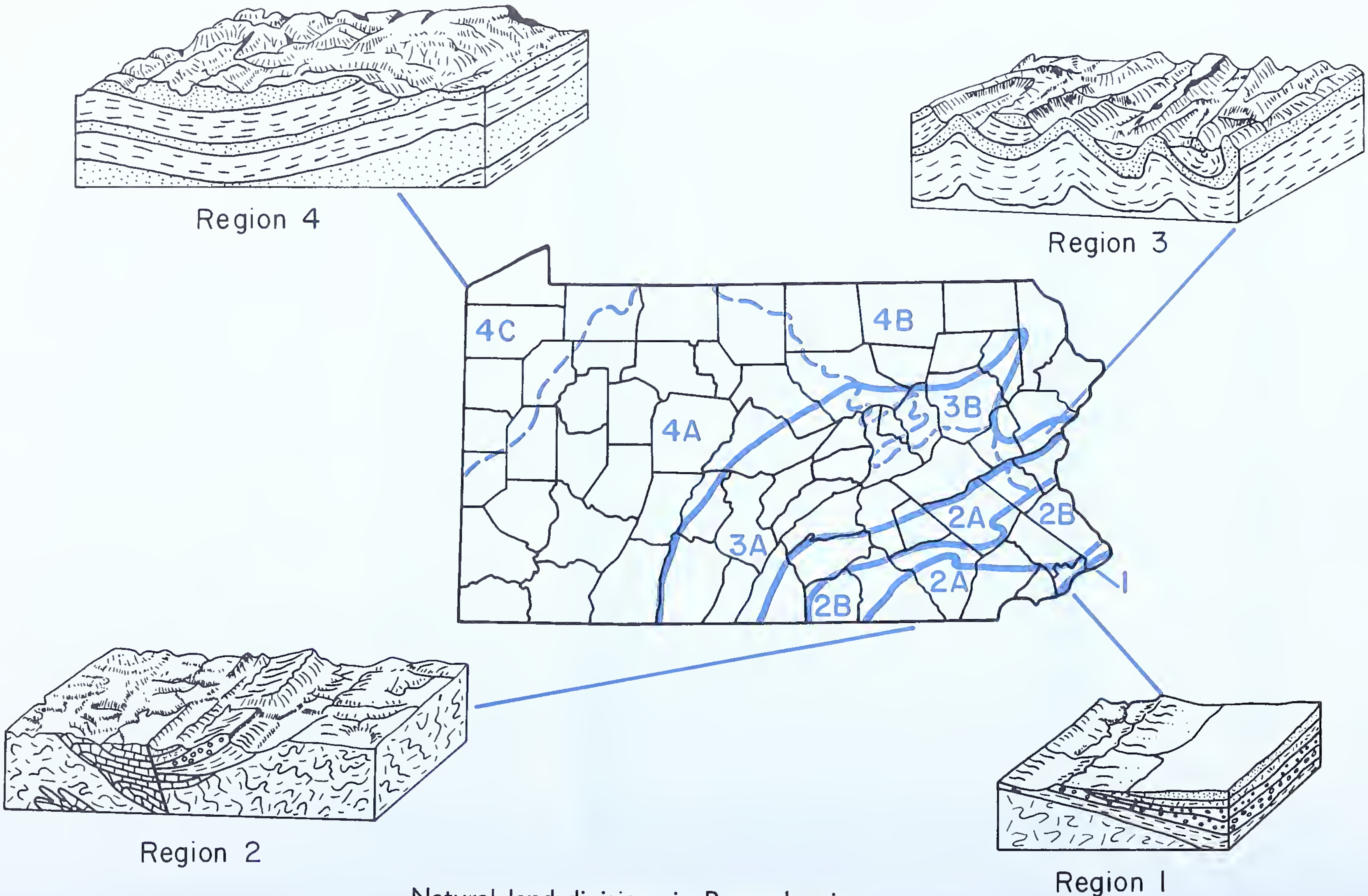
our land

Pennsylvania can be divided into four distinct regions, each having a characteristic landscape formed by the sculpturing action of natural processes on rocks of differing geologic character.

Region 1 is a narrow strip of flat lowlands underlain by unconsolidated layers of clay, sand, and gravel that are tilted very slightly to the southeast.

Region 2 is subdivided into rolling lowlands on the north and south (designated 2A) and a belt of broad highlands and ridges (designated 2B) through the middle. This region is underlain by a great variety of rock types, many of which have been intensely deformed and altered, producing the most complex geology in Pennsylvania.

Region 3 is a mountainous area consisting of long valleys underlain by limestone and shale alternating with long narrow ridges underlain by hard sandstone. The rock layers in this region have been deformed into a series of folds that differ in size and shape. Unconsolidated material of glacial origin mantles the northeastern part (designated 3B) of this region.



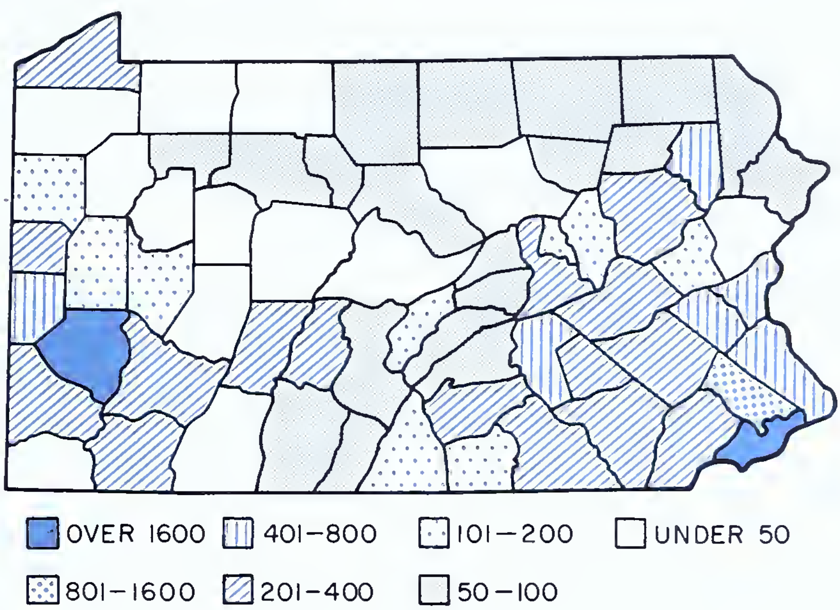
Natural land divisions in Pennsylvania

Region 4 is a rugged hilly area, mountainous in part, consisting of intricately dissected plateaus and broad ridges underlain by shale or sandstone layers that are slightly warped or gently tilted. Unconsolidated material of glacial origin covers the northeastern (designated 4B) and northwestern (designated 4C) parts of this region.

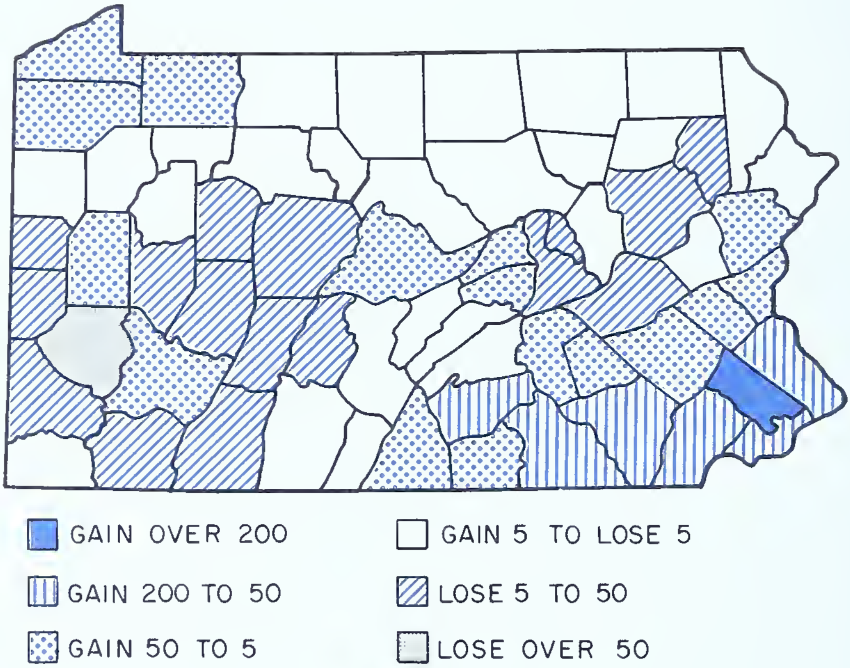
our people

Now, as in the past, Pennsylvanians have tended to concentrate in four areas of the state. In order of decreasing population, these areas are Region 1 plus most of Region 2, the southwestern part of Region 4, the eastern end of Region 3, and the extreme northwestern corner of Region 4C. Most of the rest of the state has remained relatively unpopulated.

In the past few decades, the population pattern has been changing. These changes, based on State Planning Board projections, indicate a similar changing pattern for the future. Those areas in the southwestern part of Region 4 and at the eastern end of Region 3 in which Pennsylvanians tended to concentrate in past times, are now experiencing major population declines. The remaining two areas of concentration are having major expansions of population, and a new area of population growth is forming in the center of Region 3 near the heart of the state.



Population density per square mile by county—1965



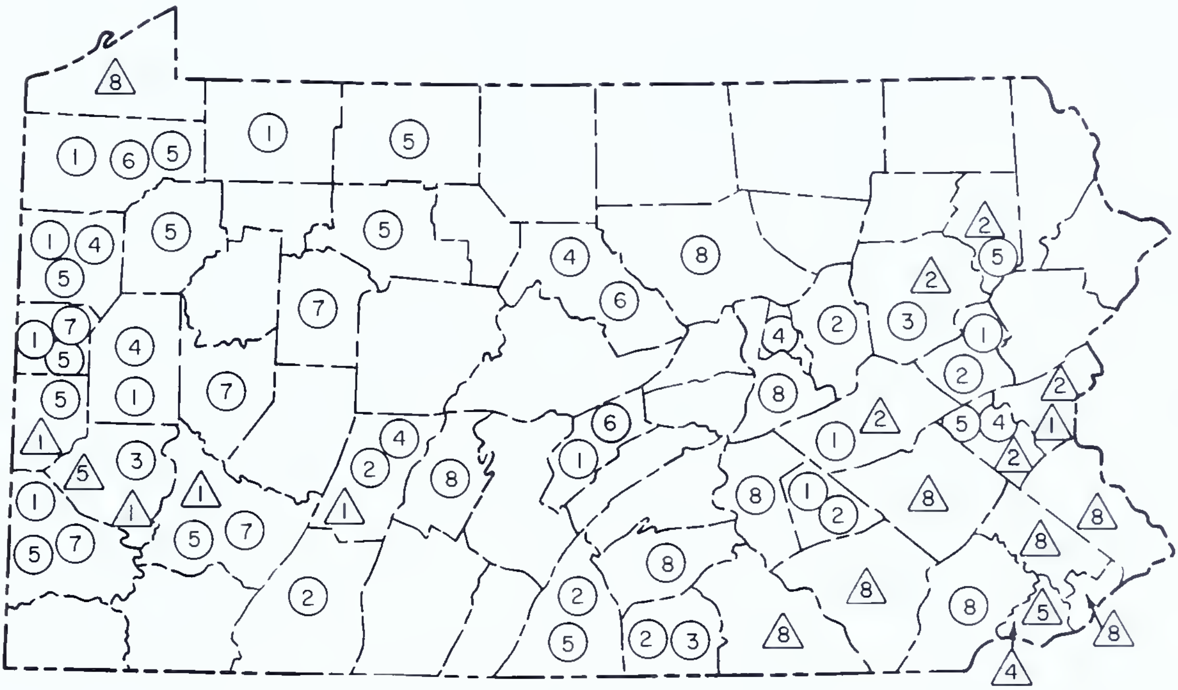
Projected gain and loss of county population in thousands—1965 to 1980

Another type of change evident in the population statistics is the shift of people from cities into nearby areas. The combination of automobiles and good high-speed roads has stimulated this shift.

our economy

There are excellent reasons why Pennsylvanians are concentrated in some areas and not others. These reasons, of course, relate to the economic development of the land, and this development depends in large part on the shape of the land and the natural resources it contains. Many of the dissected plateaus of Region 4 and the mountainous Region 3 are not easily accessible and, therefore, are largely undeveloped. However, the valuable coking coal, used by the steel industry in the southwestern part of Region 4, and the anthracite coal of the eastern end of Region 3 have promoted the economic development of these areas despite problems of accessibility. Regions 1 and 2, because of their rich flat farmland, easy access, and proximity to the coast, have been intensely developed.

The changing population pattern is a reflection of a changing economy. The decline of anthracite reserves and of demand for hard coal, and changes in the methods of making steel have reduced the job opportunities in the areas where population is declining. The construction of good highways is increasing the accessibility and, thereby, stimulating the development of a diversified economy in the central part of Region 3. Other areas of the state may be similarly opened for development in the future.



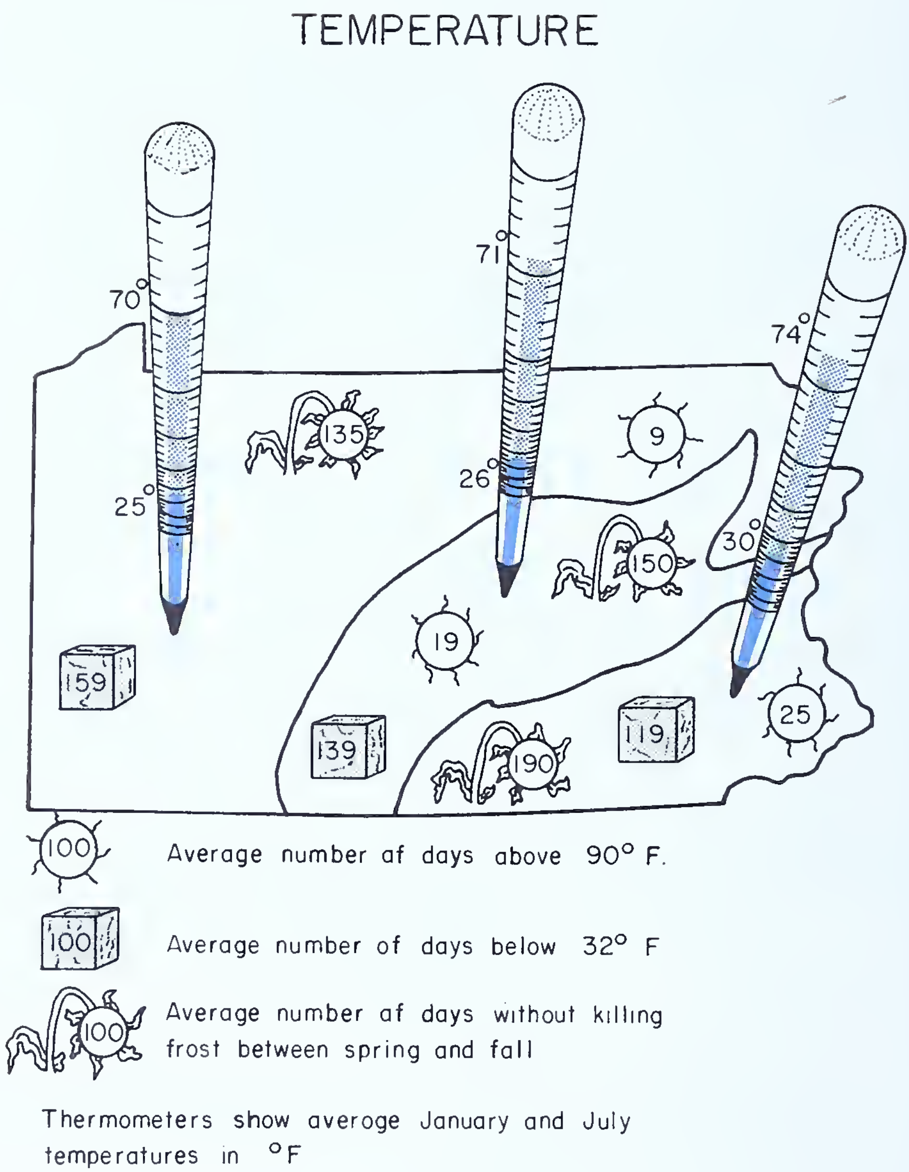
MAJOR

1 More than 10,000 employees and 10 percent of county industrial work force per industry listed below

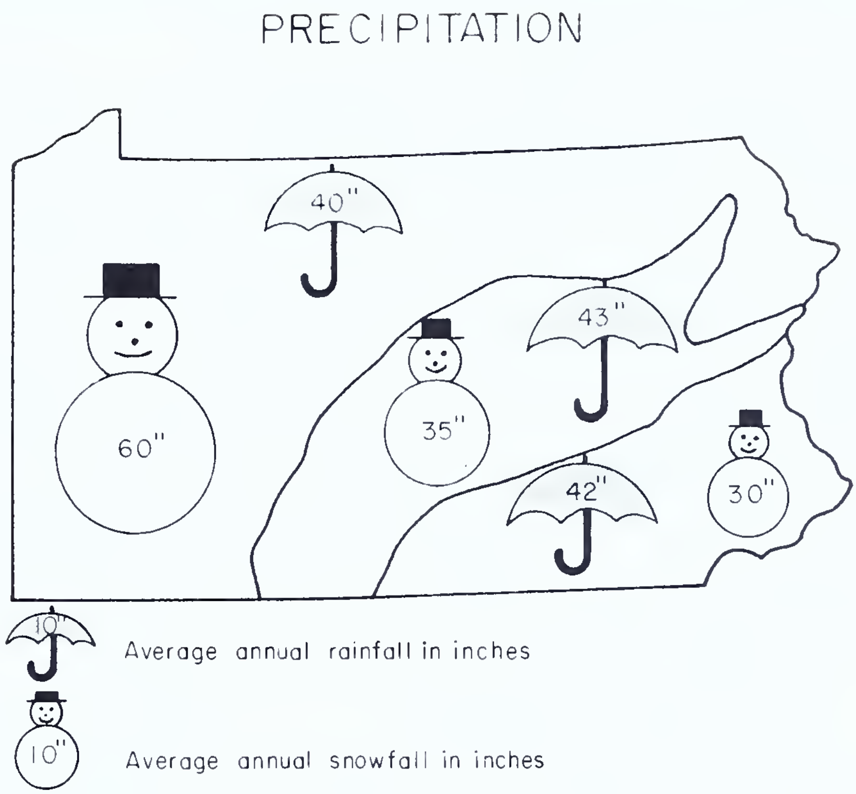
MINOR

1 More than 2,000 employees and 10 percent of county industrial work force per industry listed below

1. Primary and fabricated metal products
2. Textiles, clothing, leather and leather products
3. Food and household products
4. Transportation equipment
5. Machinery, electrical machinery, equipment and supplies
6. Chemicals and paper products
7. Stone, clay and glass products
8. Diversified industry (More than three major and/or minor industries)



Temperature

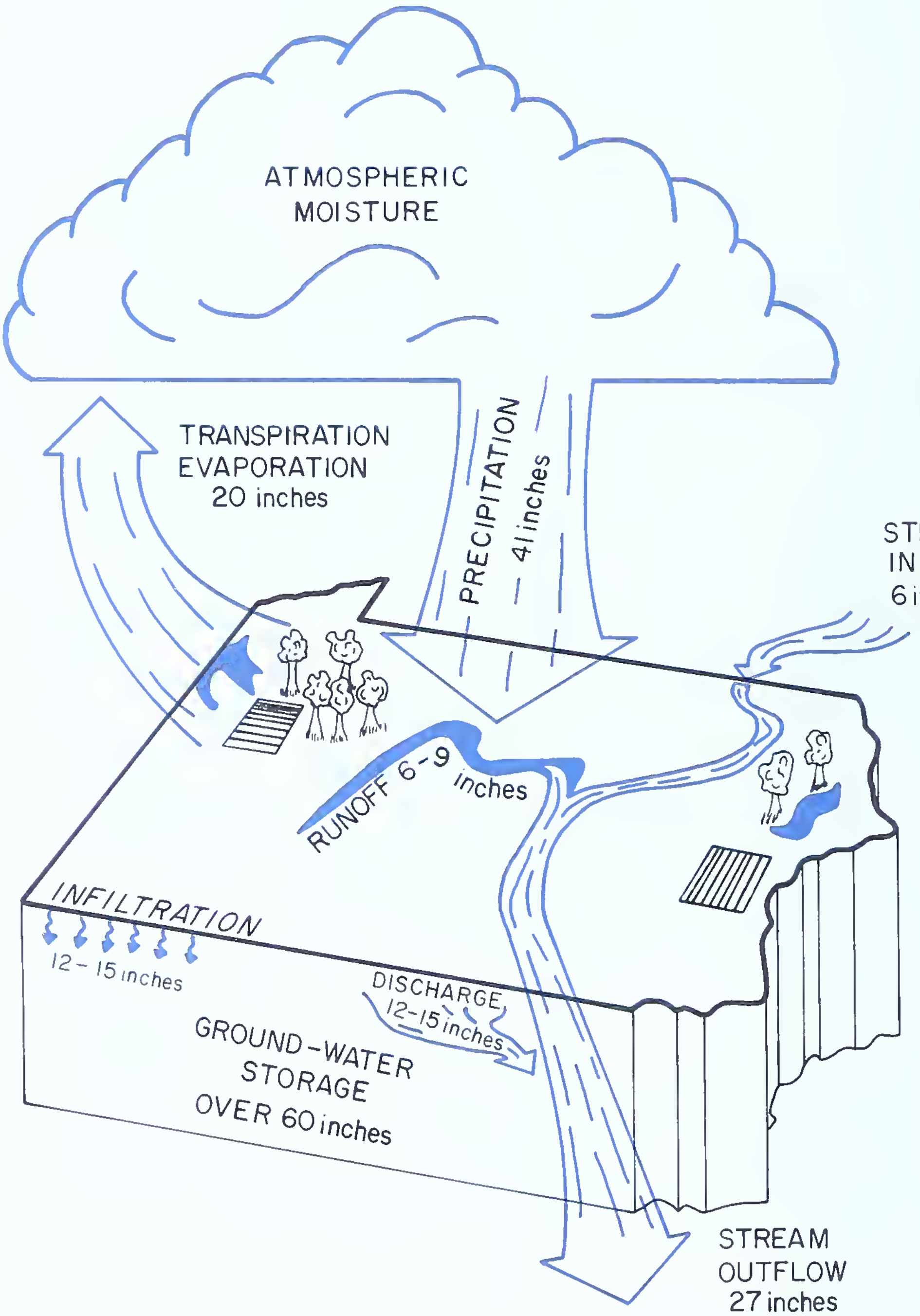


Precipitation

our climate

The large, bold landscape features of Pennsylvania modify the humid temperature climate and tend to divide the state into three climatic areas that roughly correspond to the major land regions. Some statistics about temperature and precipitation show the climatic character of the three areas.

In general, the southeastern part (Regions 1 and 2) has hotter summers and milder winters than elsewhere in the state. In contrast, the northern and western parts (Region 4) have cooler summers and colder winters than elsewhere in the state. The mountain belt (Region 3) tends to have slightly higher average rainfall than other regions, but large variations over relatively short distances are common. The spring-summer part of precipitation averages 55 to 57 percent of the total precipitation in each of the regions.



The annual water cycle in Pennsylvania

PENNSYLVANIA'S WATER RESOURCES

how much do we have?

Our water resources consist of all water stored on or in the ground plus the amounts added by precipitation and stream inflow from adjacent areas minus the amounts lost by plant transpiration, evaporation, and outflow to adjacent areas. The relationship between all these factors can be expressed as an equation.

Storage + Precipitation + Inflow — Evaporation — Transpiration — Outflow = Water Resources.

Another way of considering this relationship, more common to our everyday experience, is to think of water as money. Using this analogy, our water resources equation becomes a budget. Water in storage is equivalent to money in the bank (this is the amount available for use); precipitation and inflow are income; evaporation, transpiration and outflow are expenses. The income and expenses in the above equation change continuously in response to changes in the climatic cycle. Also, they can be changed artificially by the actions of man and such changes will either increase or decrease the amount in the bank.

PRECIPITATION

Precipitation is the source of all water in Pennsylvania. Without precipitation our trees and crops would quickly die, our streams would soon cease flowing, and ground-water levels would decline gradually.

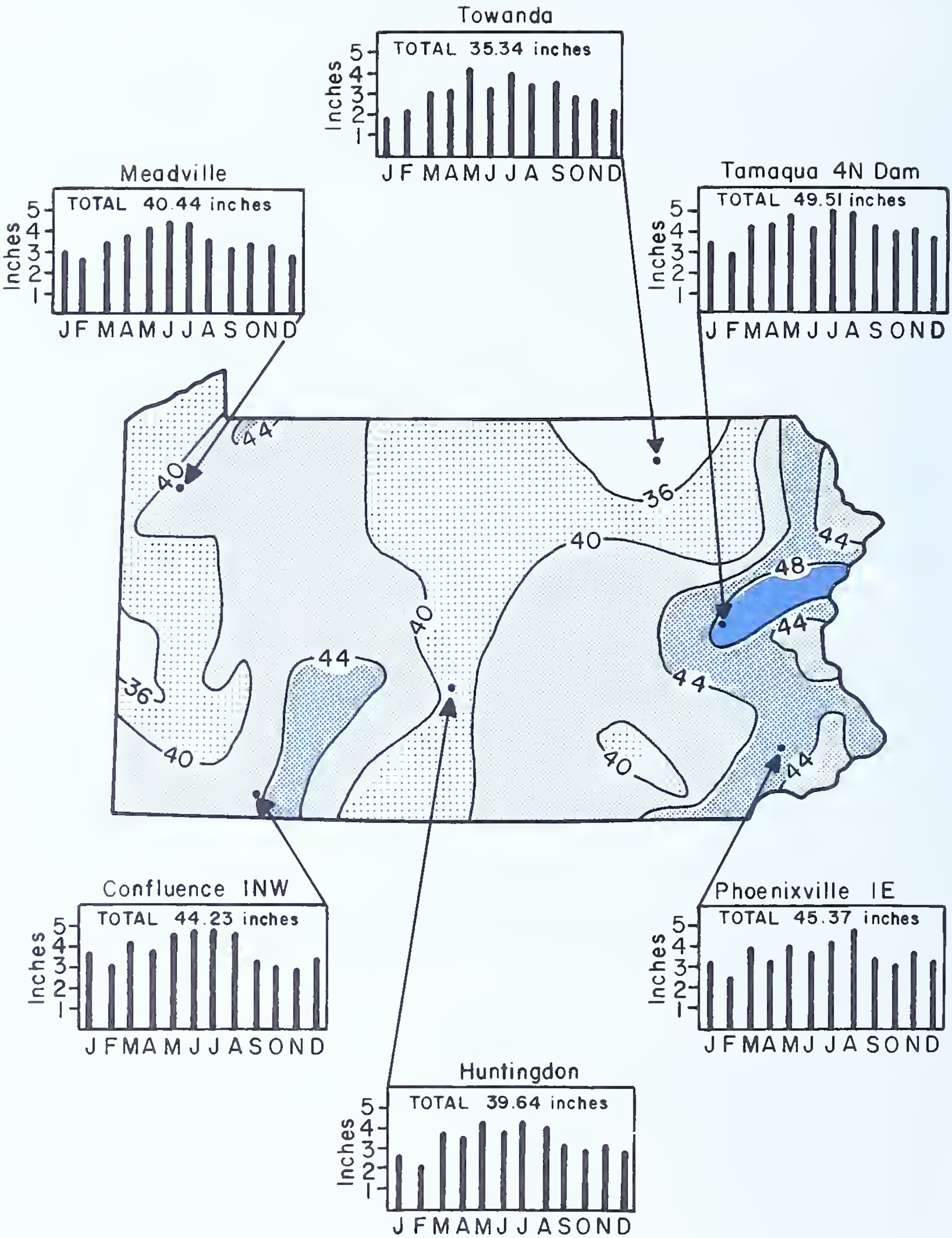
The average annual precipitation for the state is 41 inches but from place to place the average ranges between 30 and 60 inches. For any given place and year the precipitation may exceed or fall below the average by as much as 10 inches.

Between 55 and 60 percent of the precipitation occurs during the warm half of the year and most of this is in the form of intense rain storms. Precipitation during the cool half of the year occurs mostly as snow or slow, steady rain.

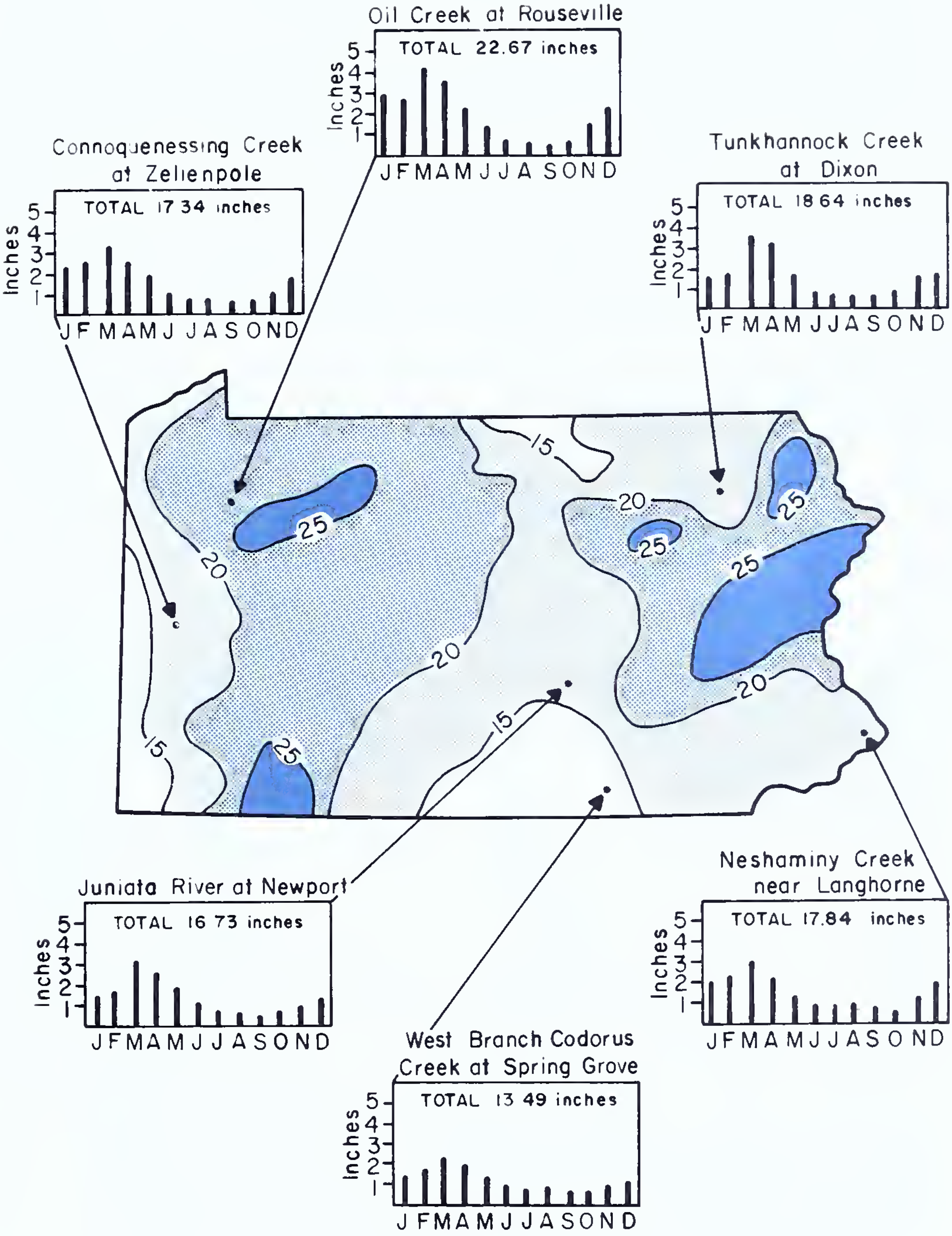
RUNOFF

Water from precipitation follows many different routes after reaching the land surface. Water that travels rapidly overland into stream channels and quickly leaves the area is called direct runoff. The equivalent of approximately 27 inches of precipitation flows out of Pennsylvania annually in streams—considerably more water than can be accounted for by direct runoff. Part of the flow comes from adjacent states, but the largest single source of streamflow is ground water.

Direct runoff accounts for 6 to 9 inches or between 15 and 22 percent of the average annual precipitation. Another 6 inches is contributed as inflow from adjacent states. The remaining 12 to 15 inches, or 60 to

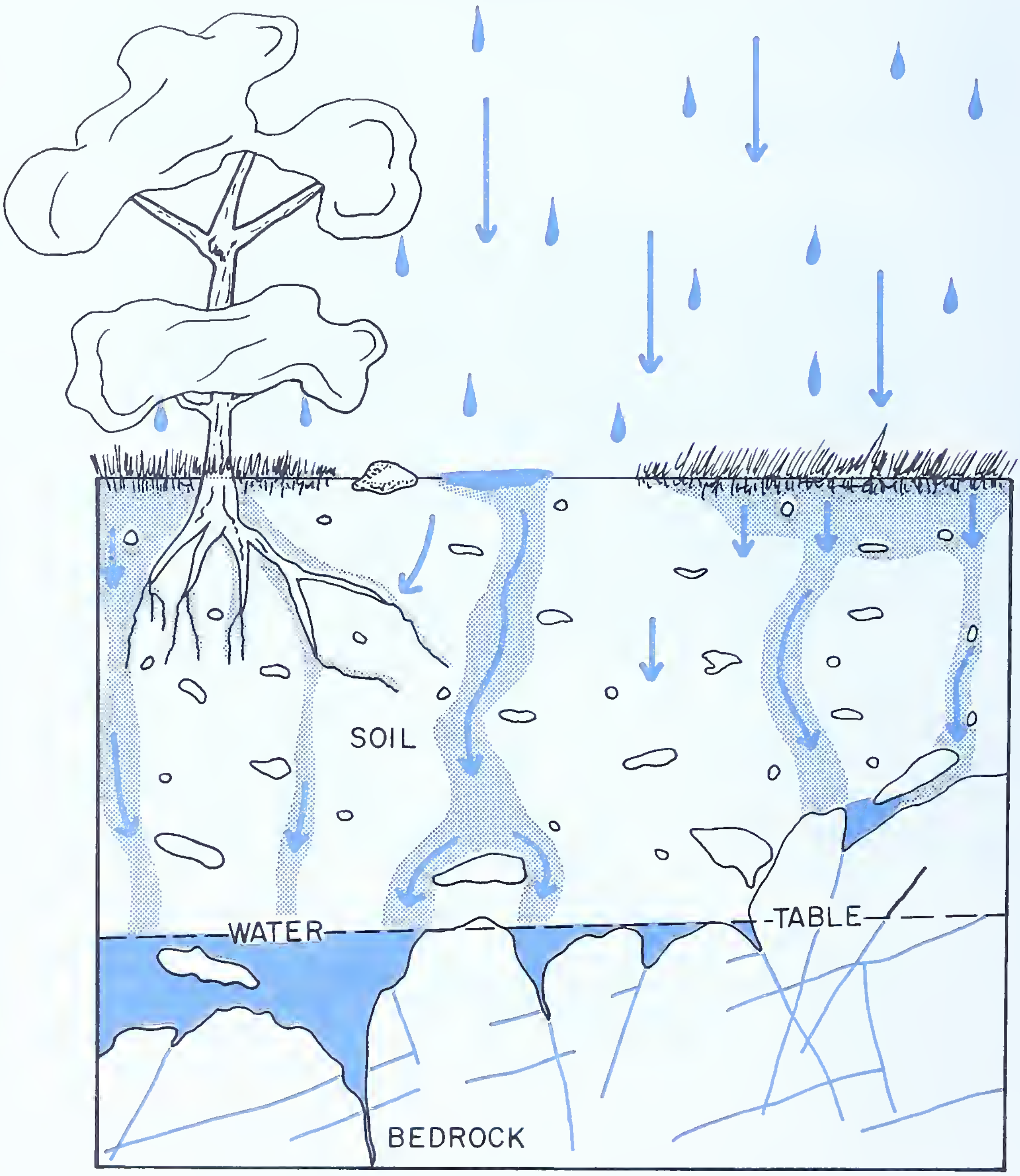


Average annual precipitation in Pennsylvania in inches



Average annual runoff in Pennsylvania in inches

70 percent of stream flow, comes from the continuous discharge of ground water by springs. For example, ground-water discharge to the Lehigh River is 77 percent of the total flow. Small streams that drain limestone terrane such as Quittapahilla Creek in Lebanon County, derive nearly 90 percent of their annual flow from ground-water discharge. Most stream channels would be dry within a few days after precipitation ended without continuous replenishment from ground-water discharges.



Infiltration replenishes our ground-water supply

INFILTRATION TO GROUND WATER

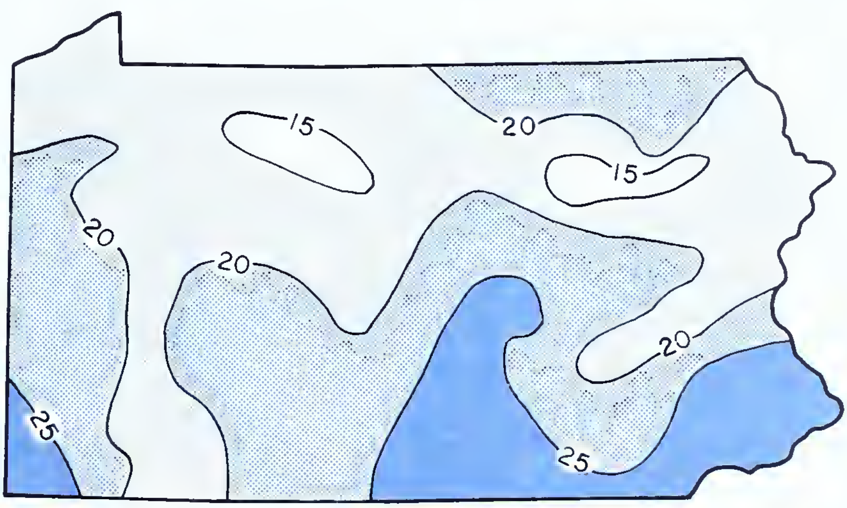
Water from precipitation that is not returned directly to the atmosphere as vapor or does not move overland as runoff infiltrates the ground. During the growing season most of the infiltrated water is intercepted by plant roots and transpired. Water that is not intercepted moves downward through the soil to the water table and replenishes the ground-water supply.

Pennsylvania's ground-water supply is replenished at a rate that averages 12 to 15 inches annually, or about one third of the average precipitation. The amount replenished by any one precipitation event is unpredictable. It depends on the type, rate, and amount of precipitation, on the season of the year, and on soil characteristics. A light, steady rain in late fall or early spring amounting to a few inches has the greatest infiltration potential. A loose, unfrozen soil having a low clay and moisture content, a high sand content, and a gentle ground slope, with a grass cover promotes high infiltration rates.

EVAPORATION AND TRANSPIRATION

A large part of the water that reaches the ground as precipitation is returned to the atmosphere by one of two processes. Some water evaporates directly from wetted surfaces such as streets, rooftops, and the ground. Some evaporates from puddles, lakes, and other bodies of water. Much is taken from the soil by plant roots and is transpired.

In Pennsylvania, about 20 inches, or almost half of the average annual precipitation, is returned to the atmosphere by evaporation or transpiration.



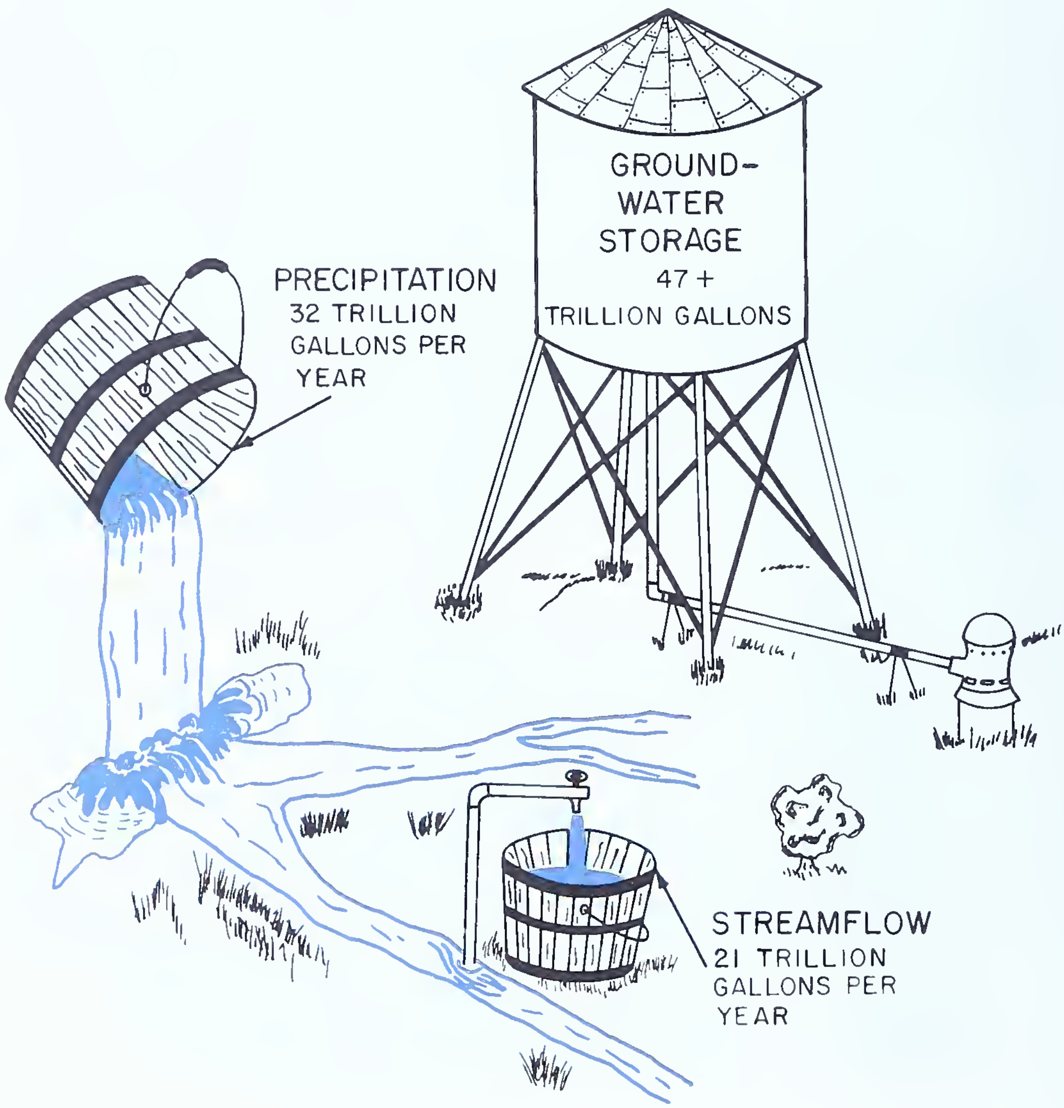
Evaporation and transpiration in Pennsylvania in inches

where do we get our water supplies?

SURFACE SOURCES OF WATER

Streams are usually sought first as a source of water supply because their waters are plainly visible, easily measurable, and readily accessible. An average of 21 trillion gallons of water, of which about two-thirds comes from ground water, flows down streams and out of Pennsylvania each year.

Many streams do not provide a dependable supply of water of the best quality available at the most economical price. Large streams, of



Sources of water supply

course, can provide large and dependable supplies of water even during periods of excessively low flow. However, most of the small streams in Pennsylvania cannot provide a dependable water supply, because periodically they are dry or reduced to a trickle. Periodic shortages can be prevented only by building impoundments that will store enough water to provide the amounts that cannot be obtained from natural flow.

Both large and small streams may be contaminated, either continuously or periodically, by waste discharges and sediment. Therefore, development of a stream to supply water for human consumption should include the construction and operation of a treatment plant.

Often impoundments and treatment plants are not the most practical or economical solutions to water-supply problems; ground water is then sought as the source or auxiliary source of supply.

SUBSURFACE SOURCES OF WATER

Below the ground in Pennsylvania water is stored in quantities greater than the total that flows down all our streams during several years. Ground water cannot be seen and is not easily measured, but it is a major source of water. A conservative estimate of the water stored below ground in Pennsylvania to a depth of about 500 feet is 47 trillion gallons. This is enough water to supply Philadelphia and Pittsburgh for about 280 years.

Each year between 9 and 12 trillion gallons of ground water is discharged naturally through springs and seeps into Pennsylvania streams, and a like amount of precipitation infiltrates back into the ground-water reservoir.

SURFACE WATER OR GROUND WATER?

A summary of advantages and disadvantages of surface and subsurface water supplies is useful in judging the relative merits of developing different sources.

Stream Water

Advantages	*Disadvantages*
Predictable yield	Requires expensive treatment and facilities
High yield	Susceptible to drought effects
Easily accessible	Large evaporation losses
	Highly variable supply
	Variable chemical quality
	Susceptible to chemical, biological, and radioactive contamination
	Variable sediment content
	Variable temperature

Impounded stream water

Advantages	*Disadvantages*
Predictable yield	High development costs
High yield	Requires expensive treatment and facilities
Easily accessible	Silting rate limits useful life
Large supply	Floods land areas
Large storage capacity	Large evaporation losses
Multi-purpose use	Variable chemical quality
	Susceptible to chemical, biological and radioactive contamination
	Variable temperature
	Moderately susceptible to drought effects

Ground water

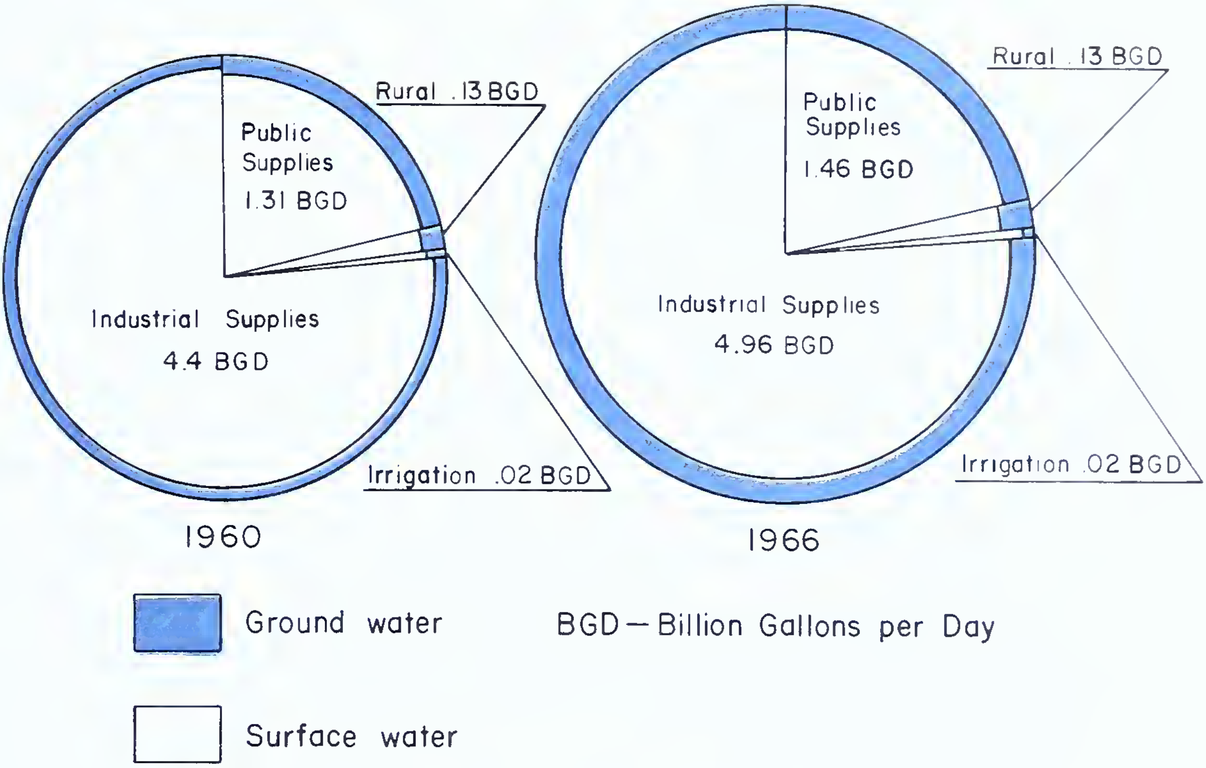
Advantages	*Disadvantages*
Low development costs	Yield difficult to predict before development
Low treatment costs	Small to moderate yield
Low cost of expanding yield	Moderate supply
Constant supply	Moderately susceptible to pollution from nearby sewage and industrial waste disposal
Relatively constant yield	
Constant chemical quality	
Constant low temperature	
Sediment free supply	
Relatively immune to drought	
No evaporation losses	
Development uses small land area	

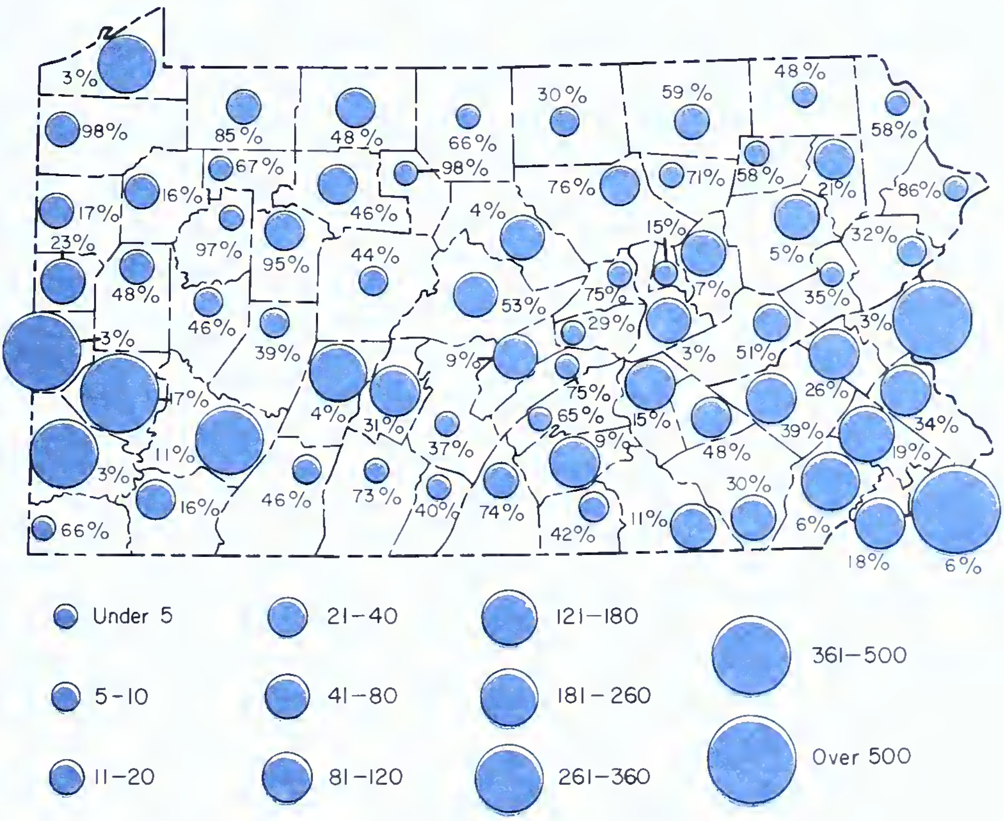
how much do we use?

Pennsylvanians used about 6.6 BGD (billion gallons per day) of water in 1966, excluding electric power plant use. Water used for cooling in thermoelectric plants and for power in hydroelectric plants is withdrawn from the stream only temporarily and does not affect the amount available to downstream users. Industry accounts for about 75 percent of the water used (excluding power plant usage), and another 22 percent is taken from public supplies for urban domestic, commercial, and industrial uses. The remaining 3 percent of the water used is supplied from private sources for rural domestic and farm needs.

Water use in Pennsylvania is increasing rapidly. The amounts of water used for industrial and public supply purposes increased 13 percent and 11 percent, respectively, between 1960 and 1966. Surface-water use reported for all purposes in the same period increased about 10 percent, compared with a 35 percent increase in ground-water use.

Although only 11 percent of the water was taken directly from ground-water sources, 25 to 35 percent of the people depend on ground water for their personal needs. In addition, 55 percent of water companies obtain all their water, and another 13 percent obtain part of their water, from ground-





Size of circle indicates water use in Million Gallons per Day.

50% - Percentage of total use obtained from ground-water sources.

Water use in Pennsylvania

water sources. As a final point to show the importance of ground water to our state, 21 of the 67 Pennsylvania counties obtain more than half their total water supplies from ground water.

what factors affect the amount of water used?

Population growth and industrial expansion are the long-term factors that influence water use in Pennsylvania. However, climatic variability temporarily influences water use and both availability and cost factors may locally affect use.

POPULATION AND INDUSTRY

As the population of a community grows, the demand for water increases proportionately. Demand will grow faster than population if industrial expansion accompanies population growth because industry uses large amounts of water.

Philadelphia is an industrial center and has been for many years. Its high per capita water use is caused by the large volume of water used by industry. In contrast, per capita use of water supplied by Philadelphia Suburban Water Company is low, reflecting the residential nature of water use in the communities north and west of the city. Recent increases in per capita use of Philadelphia Suburban water may indicate the increasing industrialization of the area it supplies.

CLIMATIC FACTORS

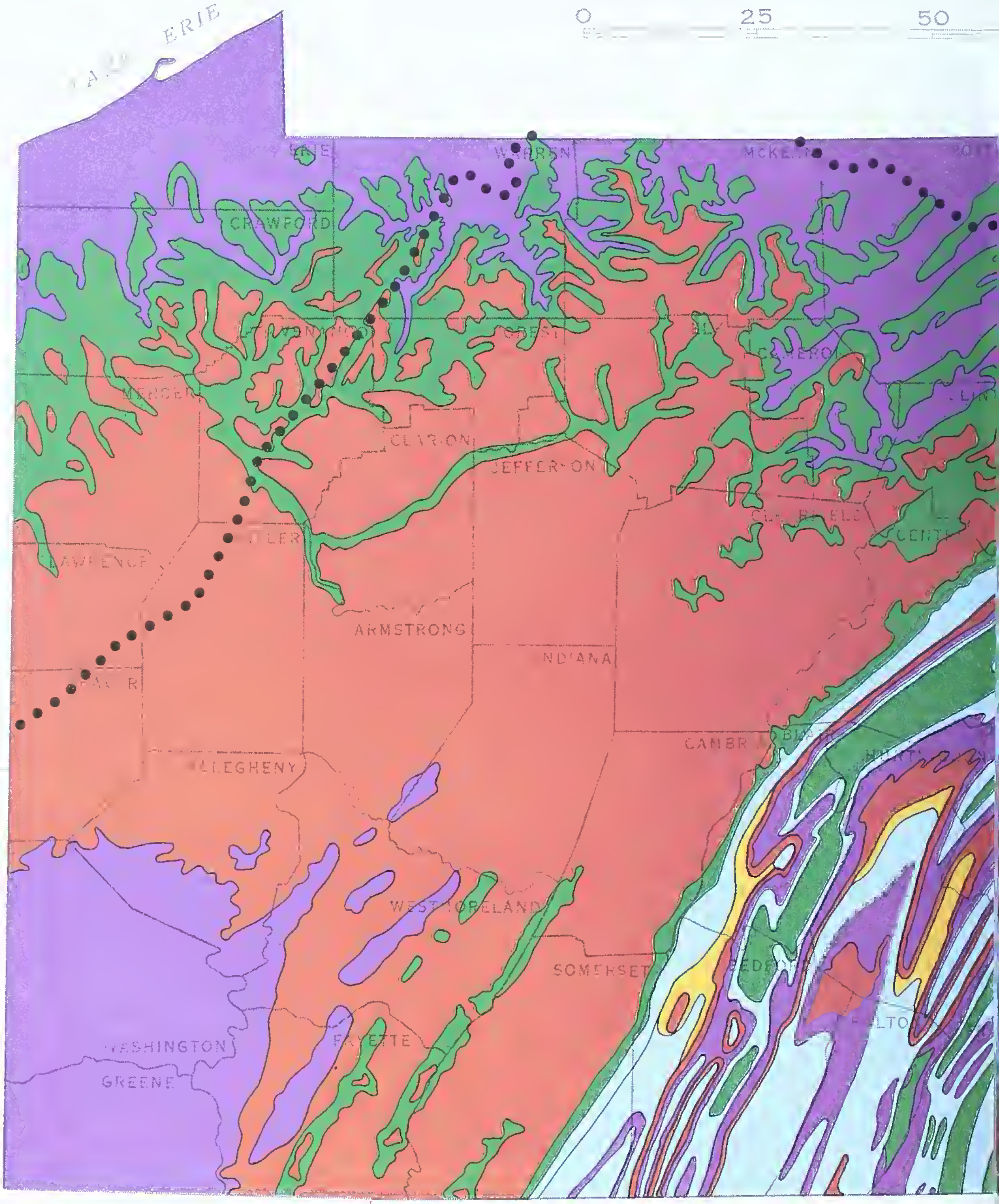
Seasonal changes, especially changes of temperature, affect water usage. The demand for water increases as we pass from spring into summer. In hot weather the demand for water is greatest. Large quantities are used in air-cooling systems, swimming pools, and on lawns and gardens. We drink more water and bathe more frequently when it is hot. As we pass from summer into fall, and temperatures decline, the demand for water also declines. Water use by the Borough of Lititz during 1968 clearly illustrates seasonal changes in use.

Natural fluctuations in the climate sometimes cause below-average precipitation for a year or more. We call such periods droughts when they adversely affect agriculture or drastically reduce the water supply. Many Pennsylvania communities experienced severe drought between 1961 and 1966. In the city of Bethlehem the cumulative effects of the drought reduced the water supply to an alarming level in 1964. Long-term water-use restrictions were put in force in July of 1964, and even stricter measures were taken in June of 1965.

WATER YIELDING
OF ROCKS
PENNSYLV

Scale

0 25 50



ESTIMATED MEDIAN YI

Median yield is the yield in the middle of the range of yields of a rock formation. Each of the five colors on the map includes several formations, each with its own median yield figure. The range given for each color is from the formation with the highest median yield.

10 to 25 | 26 to 50 | 5

•••••••• Southe

APABILITY
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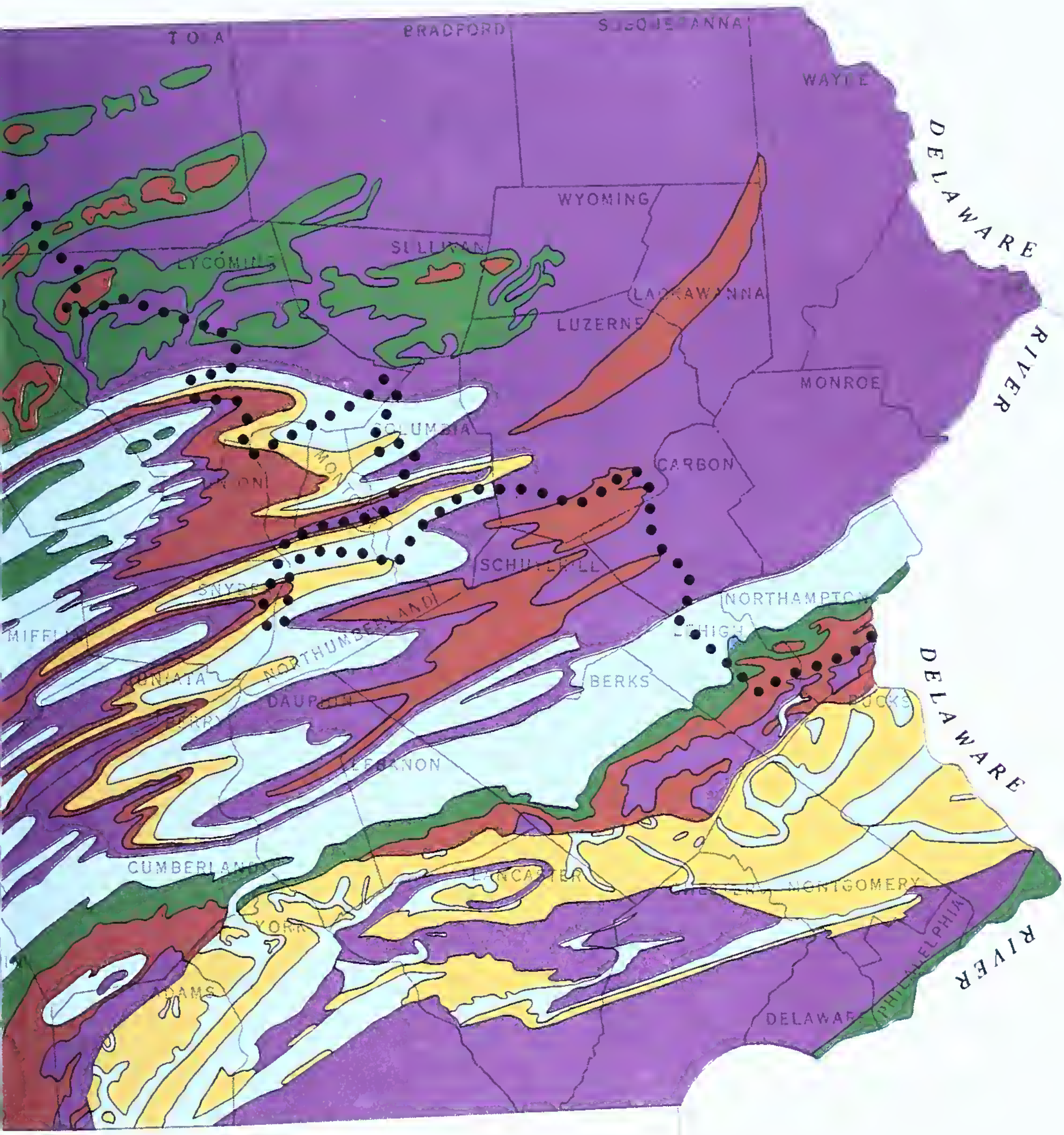
TOPOGRAPHIC AND GEOLOGIC SURVEY
ARTHUR A. SOCOLOW, *State Geologist*

75 100 miles

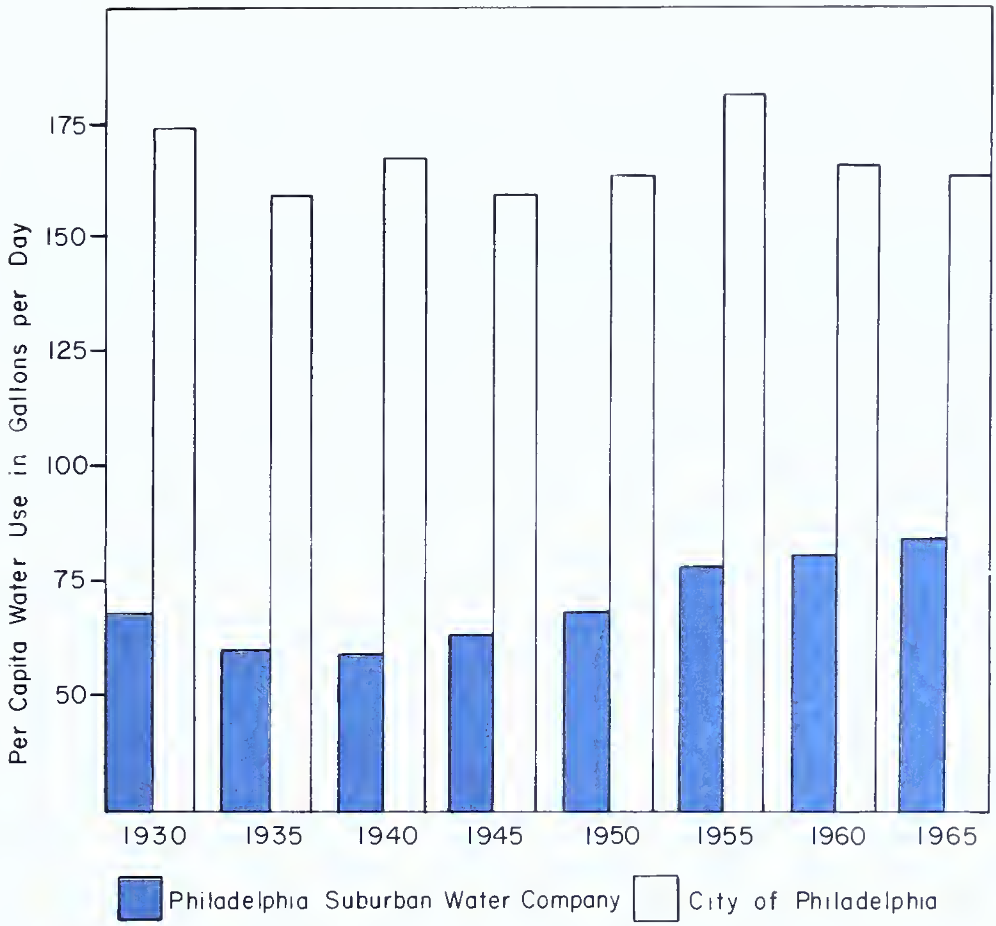


D (gpm) OF BEDROCK UNITS

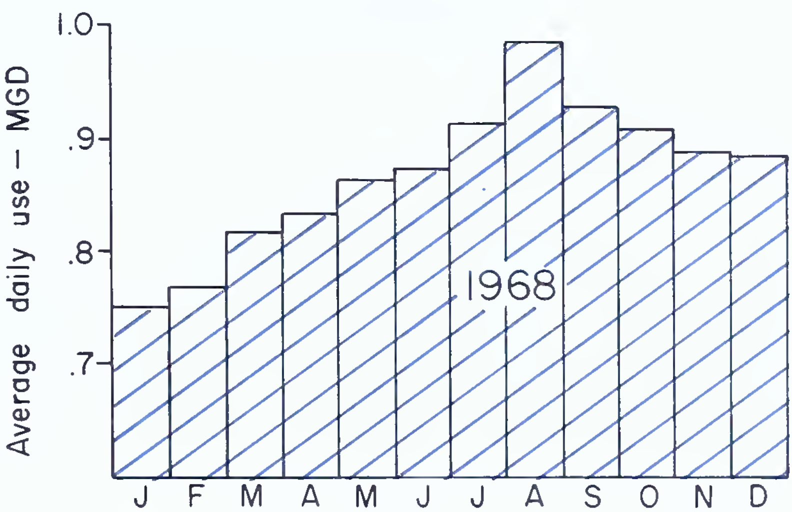
100 | 101 to 200 | 201 to 850

limit of glacial deposits

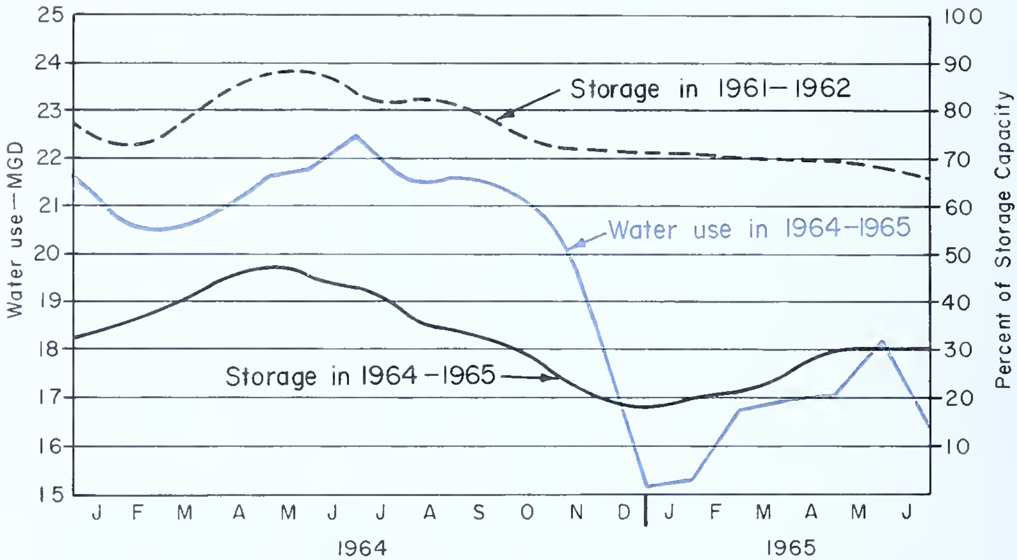
Yields of wells in glacial and stream deposits of sand and gravel range from 20 to 2000 gpm.



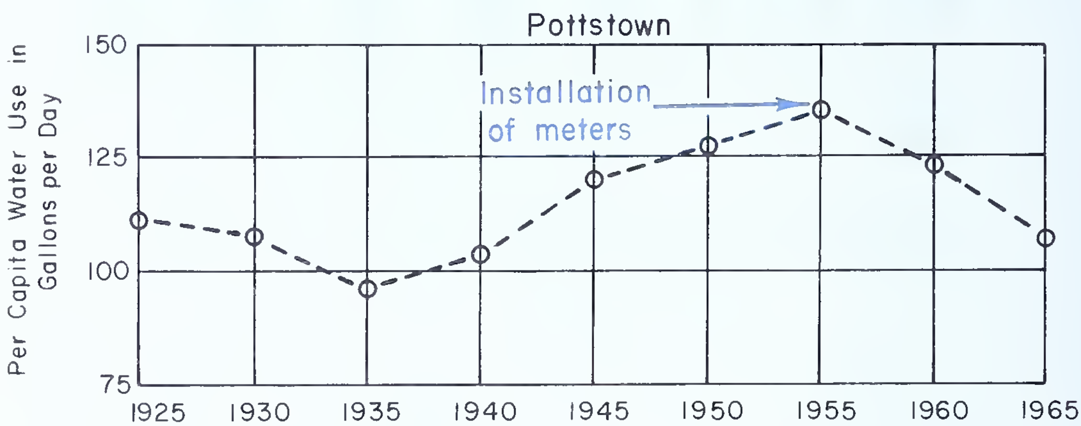
Differences in per capita water use between urban and suburban communities



Ground-water pumpage by the Borough of Lititz



The effect of drought on reservoir storage and water use for the City of Bethlehem



Decline in per capita water use after installation of meters

AVAILABILITY AND COST FACTORS

Per capita use of water is high where supplies are abundant and people feel free to use water lavishly. Conversely, per capita use is low where the supply is inadequate to meet demands and conservation must be practiced.

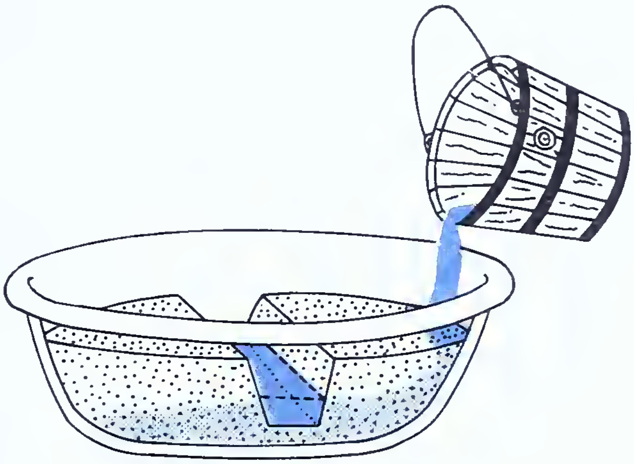
Costs inversely affect per capita use of water. Where costs are low per capita use is high, but where costs are high per capita use is low. For example, water systems supplying unmetered water generally show a sharp

decline in per capita use when meters are installed and charges are made based on the amount used. Per capita use of water in Pottstown, for instance, increased between 1935 and 1955, following the national trend, but decreased after Pottstown started installing meters in 1955.

PENNSYLVANIA'S GROUND WATER

geology and ground water

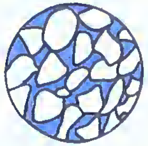
Ground water is stored in and moves through interconnected openings below the water table in the subsurface of Pennsylvania. Two types of ground-water reservoirs, or aquifers, exist—based on the kind of openings in which water occurs.



Unconsolidated aquifers are like sand-filled basins

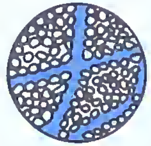
The unconsolidated aquifer contains water in void spaces between adjacent mineral grains. This type of aquifer is analogous to a basin filled with sand into which water is poured. Unconsolidated aquifers consisting of sand and gravel occur above the bedrock surfaces in the northwest and northeast parts, in the extreme southeastern corner, and in some major stream valleys of the state.

Sand and Gravel (magnified)



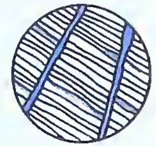
Large amounts of water are stored and can move freely around gravel and grains of sand. Yields 50-1000 gpm to wells, depending on thickness of yielding zone and size and uniformity of grains. Water is naturally soft and low in mineral content.

Sandstone (magnified)

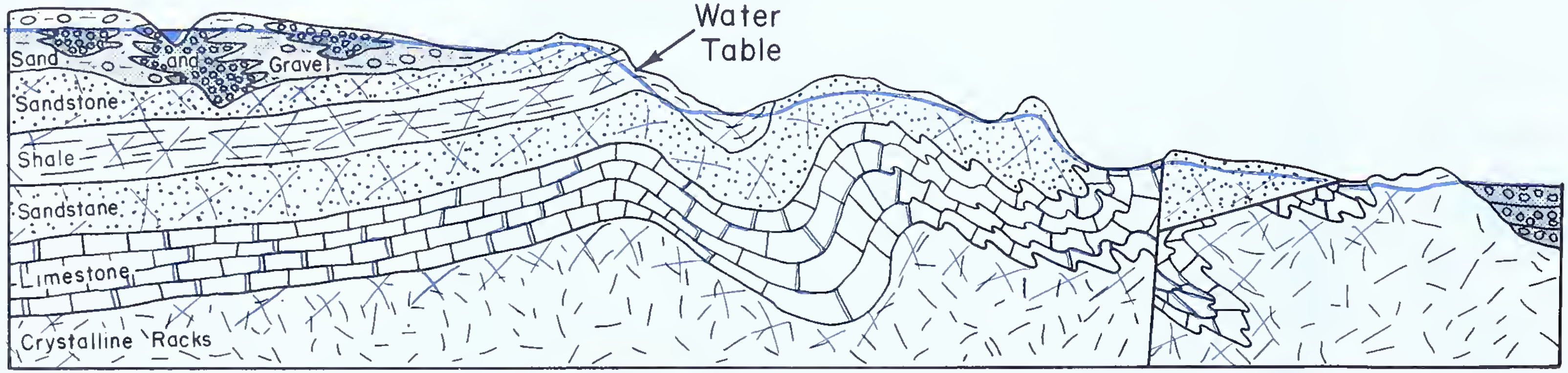


Moderate amounts of water are stored and can move through a network of narrow cracks formed by intersecting fractures and openings between rock layers. Commonly yields 10-60 gpm of soft, slightly mineralized water to wells.

Shale (magnified)



Moderate to large amounts of water are stored but can move with difficulty through a network of fine cracks formed by intersecting fractures and openings between rock layers. Commonly yields 5-25 gpm of hard, moderately mineralized water to wells.



Limestone (magnified)

Small to large amounts of water are stored and move easily through solution channels, fractures, and openings between rock layers. Commonly yields 5-500 gpm of very hard, mineralized water to wells.

Crystalline Rocks (magnified)

Small to moderate amounts of water are stored and can move with difficulty through a network of fine cracks opened by fractures. Commonly yields 5-25 gpm of soft, slightly mineralized water to wells.

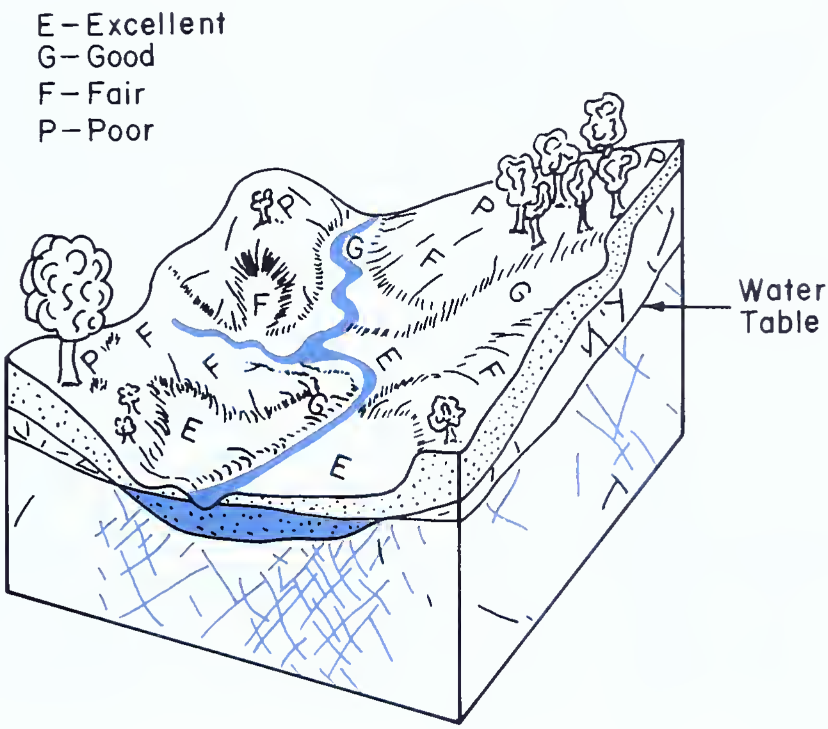
The general geology and water-bearing properties of rocks in Pennsylvania

The bedrock aquifer contains water in a network of openings formed by intersecting fractures, solution cavities and separations between rock layers, as well as in spaces between grains. Bedrock aquifers occur throughout the state. They are composed of sandstone, shale, limestone, combinations of these rocks, and crystalline rocks.

developing a ground-water supply

SELECTING A WELL SITE

Often the difference between a successful well and one that fails to yield the supply of water needed is its location. A knowledge of the relationship that exists between topography and the relative yields of bedrock wells will increase the chances of drilling a successful well. It has been observed, in general, that wells drilled in draws or stream beds have excellent yields, those in valleys have good yields, those on slopes and hillsides have fair yields, and those on ridges or near hilltops have poor yields. Draws and valleys are best, primarily because they com-



How topography reflects well-site potential

monly form where rocks are most intensely fractured and, therefore, are weathered and eroded most rapidly. Also, such lowlands are the eventual collecting areas through which all ground water drains under the influence of gravity.

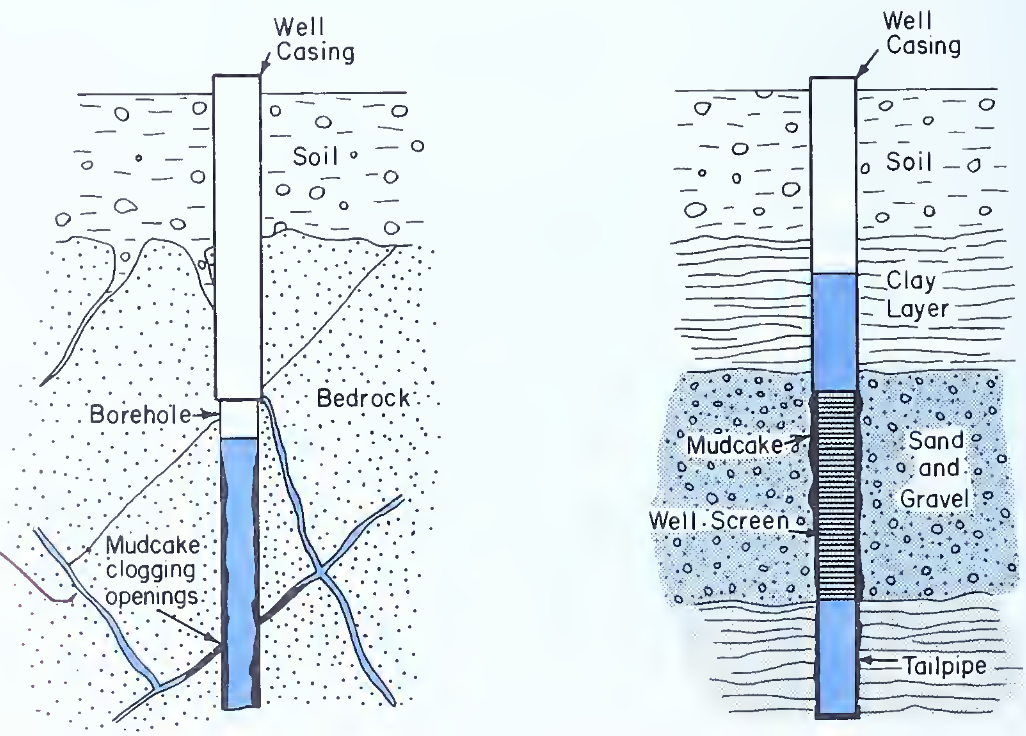
Other factors used in selecting a well site may require study and more technical evaluation. Such factors include determining the relative merits of all available aquifers, locating fractures or zones of fracture, locating possible sources of pollution, and determining costs.

OBTAINING THE MAXIMUM YIELD

After a well has been drilled, further steps may be necessary to obtain the maximum potential yield.

Openings penetrated by wells in *bedrock aquifers* may become clogged by a mudcake formed during drilling. The mudcake may be removed by pumping the well at a high rate, by surging, or by use of a dispersing agent. Surging consists of moving a plunger up and down in the borehole. One of several polyphospate compounds may be used to disperse clay particles in conjunction with surging.

Intergranular spaces in *unconsolidated aquifers* may be clogged with mudcake or partly blocked by clay and fine sand particles. This mate-



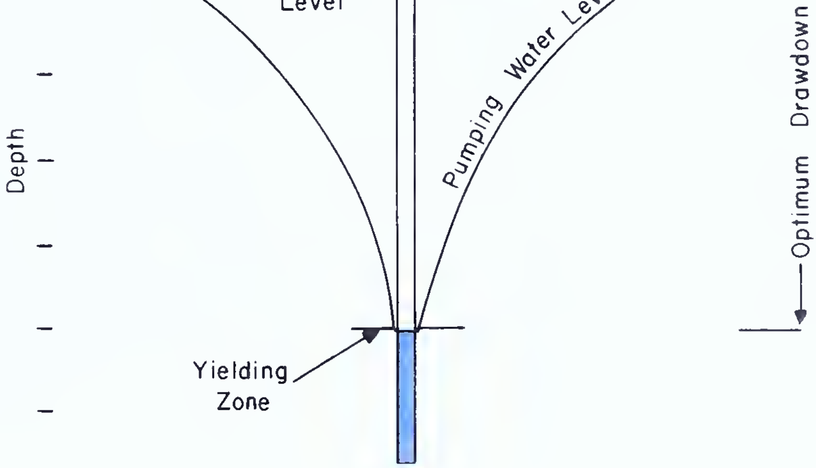
Bedrock aquifer well—Unconsolidated aquifer well

rial is removed through the slots in a well screen by the same general methods used for bedrock aquifers.

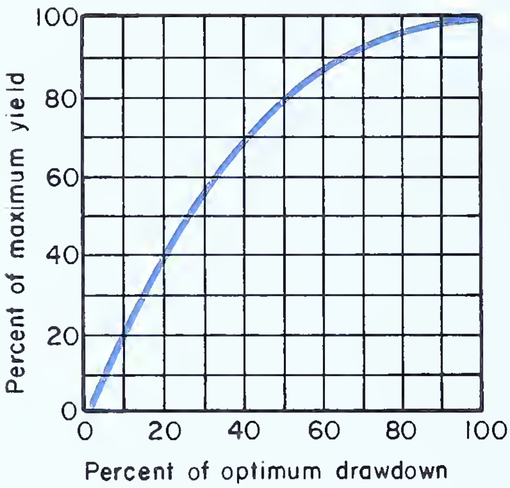
MEASURING THE YIELD

The most common questions asked by Pennsylvanians interested in developing a ground-water supply have to do with yield. For the homeowner and farmer the question is about the short-term yield of his well, especially in relation to domestic needs.

When a well is pumped the water level declines rapidly until flow from the aquifer into the borehole is equal to the pump discharge. Then the water level may stabilize or continue to decline slowly—depending on whether or not equilibrium has been achieved in the aquifer surrounding the well. Maximum flow into the borehole is induced by increasing the rate of discharge until the water level is lowered to the yielding zone (optimum drawdown of the well). This rate is the maximum yield of the well even though the pump capacity may permit a higher yield, on a short term basis, by pumping water stored in the borehole below the yielding zone. When the capacity of the pump is less than needed to produce the optimum drawdown, the maximum yield still can be esti-



Maximum yield and optimum drawdown



Graphic determination of the percent of maximum yield when the percent of optimum drawdown is known

mated. A graph showing the average relationship between optimum drawdown and maximum yield can be used to calculate the maximum yield within about 20 percent.

For example, what is the maximum yield of a well that has a drawdown of 50 feet while yielding 80 gpm from a zone 100 feet below static water level? As the drawdown is 50 percent of the optimum drawdown, the graph indicates that the yield is probably about 80 percent of the maximum yield. Therefore,

$$\text{Maximum yield} = \frac{80 \text{ gpm}}{80 \text{ percent}} \times 100 \text{ percent} = 100 \text{ gpm}$$

SPECIFIC CAPACITY

A simple way of estimating the yield capability of a pumping well, for purposes of comparison with other wells, is to divide the rate of discharge (gpm) by the drawdown (feet). The quotient, called the specific capacity of the well (gallons per minute per foot of drawdown), can be compared with the specific capacities of wells that have different drawdowns. In general, the larger the specific capacity, the larger the yield capability of the well. Higher rates of pumping or longer periods of pumping will lower the specific capacity of a well. Therefore, the best comparisons are between wells that have been pumped at similar rates for like periods of time.

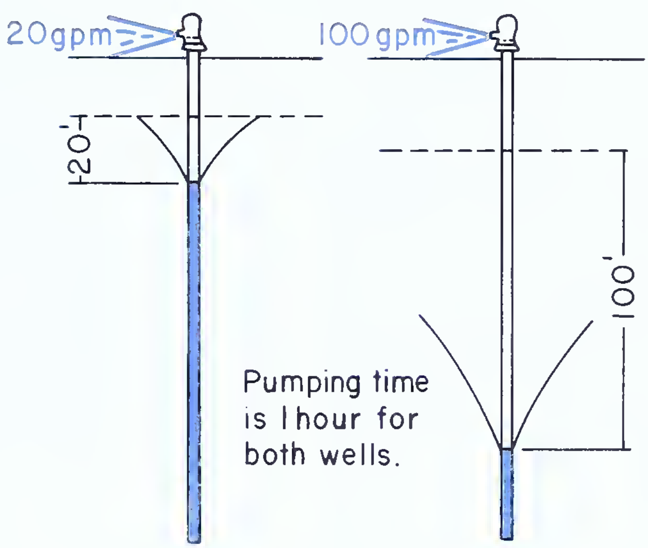
yielding capability of rock units

The regional or local planner, water manager, or developer wants information about several different aspects of yield. One of these is the relative yield capability of each rock unit in his borough, township, county, or other area of interest. While many still talk of yield in terms of gallons per minute, specific capacities obtained from pump tests on many wells throughout the state provide a basis for estimating the yield capability of rock units. The median (middle value in a list of ordered numbers) specific capacity of wells in each rock unit, or group of units, was used to compute a median yield. The computation assumes that 50 feet of drawdown is available in the average well and that yield is directly proportional to drawdown. Median yields of similar magnitude were grouped together and used to color code the centerfold map.

Only the approximate southern limits of glacial sand and gravel deposits are shown on the centerfold map. Thick deposits of sand and gravel may also be present in major stream channels farther south. The median yield of such glacial deposits is about 700 gpm.

The specific capacities of wells, their estimated yields, and the chemical nature of their waters are summarized in the following table, according to the major geologic units or groups of units used to color

$$\text{Specific Capacity} = \frac{20\text{ gpm}}{20\text{ feet}} = 1\text{ gpm/ft} \qquad \text{Specific Capacity} = \frac{100\text{ gpm}}{100\text{ feet}} = 1\text{ gpm/ft}$$



Specific capacity allows comparison of wells pumped at different rates

Summary of aquifer yield capability and water quality

Geologic age	Name of units	Rock type	Specific capacity (gpm per foot) Percent [1] 75 Low	50 Median	25 High	Estimated yield [2] (gpm) Low	Median	High	Chemical quality of water: Median dissolved mineral content [3]	Median hardness [4]	Undesirable chemicals that are sometimes present	Remarks
						REGION 1						
Quarternary and Cretaceous	Includes all Coastal Plain deposits	Sand, gravel, clay	8	17	25	400	850	1,250	Average		Moderately hard	High in Fe, SO_4, Cl, Ca, Mg, in some areas due to contamination
						REGION 2A						
Precambrian	All crystalline rocks except schists	Gneiss, granite, etc.	.37	.84	1.9	18	42	95	Low	Moderately hard	High Fe	
Probably Early Paleozoic	Wissahickon and equivalent units	Schists	.21	.93	4.4	10	46	220	Low	Soft		
Cambrian	Chickies, Harpers, Antietam, Hardyston	Quartzite, phyllite	.14	.48	1.7	7	24	85	Low	Soft		
Cambrian	Tomstown, Waynesboro, Elbrook, Allentown, Conococheague	Dolomite, limestone	.45	2.5	15	22	125	750	High	Very hard		North of Region 2B
Cambrian	Vintage, Kinzers, Ledger, Zooks Corner, Conococheague	Dolomite, limestone	.20	.9	5.2	10	45	260	High	Very hard		South of Region 2B
Ordovician	Beekmantown, Jacksonburg, Hershey, Myerstown, St. Paul, Chambersburg	Limestone, dolomite	1.1	7.4	45	55	370	2,250	High	Very hard		North of Region 2B
Ordovician	Beekmantown, Conestoga	Limestone, dolomite	18	1.1	6.9	9	55	345	High	Very hard		South of Region 2B
Ordovician	Cocalico, Martinsburg	Shale	20	.50	1.0	10	25	50	Low	Hard	H_2S gas	

						REGION 2B						
Triassic	Brunswick-Gettysburg	Sandstone, shale, conglomerate	.32	1.6	10	16	80	500	High	Hard		
Triassic	Lockatong	Shale	.10	.24	.65	5	12	32	High	Very hard		
Triassic	Stockton	Sandstone, conglomerate	1.1	1.9	11	55	95	550	Average	Hard		
Triassic	New Oxford	Sandstone, conglomerate	.35	1.0	2.8	17	50	140	Low	Hard		Lancaster County
Triassic	New Oxford	Sandstone, conglomerate	.20	.50	1.	10	25	55	Average	Hard		York County
Triassic	New Oxford	Sandstone, conglomerate	.14	.28	.56	7	14	23	Average	Hard		Adams County
						REGION 3						
Pennsylvanian	Post-Pottsville, Pottsville	Sandstone, shale, conglomerate	.87	2.1	5.3	43	105	265	Low	Moderately hard		Pottsville water is usually soft [5]
Mississippian	Mauch Chunk, Pocono	Shale, sandstone, conglomerate	.46	.82	1.6	23	41	80	Low	Moderately hard		Pocono water is usually soft
Devonian	Susquehanna	Sandstone, shale	.14	.42	1.3	7	21	6	Low	Moderately hard	H_2S gas	
Devonian	Hamilton, Onondaga, Mahantango	Shale, limestone, sandstone	.40	1.0	3.3	20	50	165	Low	Moderately hard	H_2S gas	Mahantango water is hard and high in dissolved mineral content
Devonian and Silurian	Oriskany, Helderberg, Tonoloway, Keyser	Limestone, sandstone, shale	.84	2.4	12	42	120	600	Low	Hard	High $CaSO_4$ in Helderberg	Oriskany water is only moderately hard
Silurian	Wills Creek, Bloomsburg, McKenzie, Clinton	Shale, limestone, sandstone	.33	.75	1.6	16	37	80	High	Very hard	High $CaSO_4$ in Wills Creek	Clinton water is soft and low in dissolved mineral content
Silurian and Ordovician	Tuscarora, Juniata, Bald Eagle, Reedsville	Quartzite, shale, conglomerate	.26	.36	.54	13	18	27	Low	Soft	H_2S gas in Reedsville	Reedsville water is moderately hard
Ordovician	Beekmantown and Middle Ordovician limestones	Limestone, dolomite	.60	4.6	45	30	230	2,250	High	Very hard		
Cambrian	Mines, Gatesburg	Dolomite	.45	9.8	21	22	490	1,050	Average	Hard		

Summary of aquifer yield capability and water quality (continued)

REGION 4

Quaternary and Pleistocene	Surficial stream and glacial deposits	Sand, gravel, clay	4.4	14	46	320	700	2,300	Water quality is variable and depends on minerals present in deposits and on stream water quality			Unit also present in Region 3
Permian and Pennsylvanian	Greene, Washington, Monongahela	Shale, sandstone, limestone	.37	.60	3.0	18	30	150	Low	Moderately hard	[6]	Water from limestone is hard and high in mineral content[5]
Pennsylvanian	Conemaugh, Allegheny, Pottsville	Shale, sandstone, limestone	.85	3.3	13	42	165	650	Low	Moderately hard	[6]	Water from limestone is hard and high in mineral content[5]
Mississippian	Mauch Chunk, Pocono	Shale, sandstone, conglomerate	1.5	4.3	12	75	215	600	Low	Moderately hard	[6]	[5]
Devonian	Susquehanna	Sandstone, shale	.29	.96	3.4	14	48	170	Average	Soft	H_2S gas[6]	[5]

[1] Percentage of wells that have specific capacities greater than the given values.

[2] Yields calculated from the low, median, and high specific capacities using an arbitrary drawdown of 50 feet.

[3] Low—< 200 ppm; average—201 to 250 ppm; high—> 250 ppm.

[4] Soft—< 60 ppm; moderately hard—61 to 120 ppm; hard—121 to 180 ppm; very hard—> 180.

[5] Acid water commonly present near coal mines.

[6] Saline water occurs at depths as shallow as 300 feet under valleys.

The geologic nomenclature in this report does not necessarily agree with that of the U.S. Geological Survey.

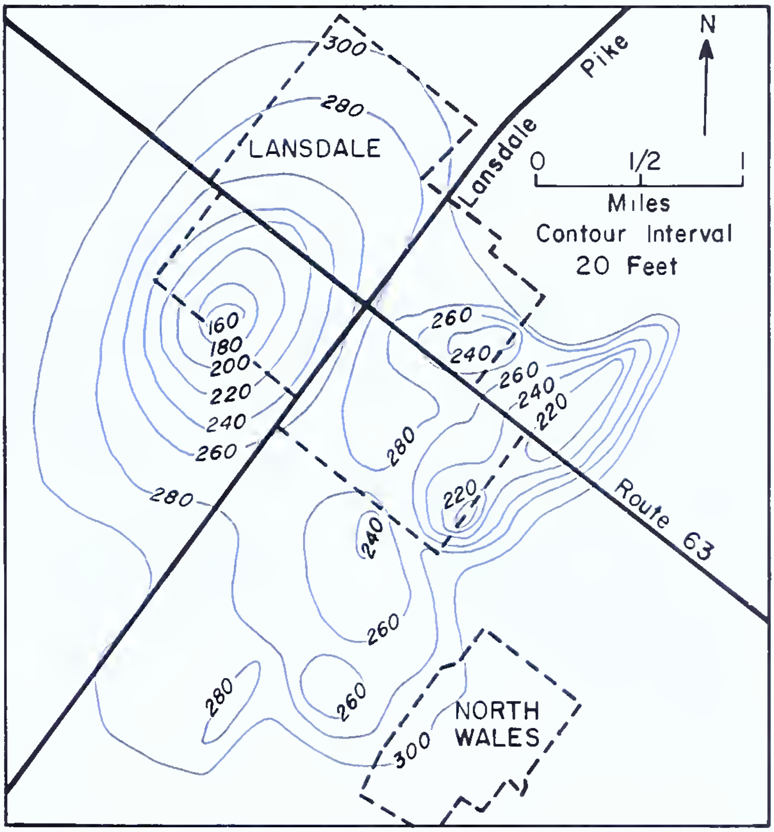
code the centerfold map. To determine the geographic limits of exposures of these units, or groups of units, refer to the large-scale Geologic Map of Pennsylvania (Map 1) published in 1960 by the Pennsylvania Geological Survey.

OUR WATER PROBLEMS

Water problems in Pennsylvania are mostly related to the effects of pollution, but some problems of inadequate local supply also exist. Problems related to both the quantity and quality of water probably will become more prevalent as the growing population and industrial expansion demand even greater supplies of water.

problems of quantity

No broad, regional problems of water shortage or continuously declining ground-water levels exist in Pennsylvania. A few local areas have



Contour lines on water table show altitude above sea level (1954)

Contour map showing the amount and extent of lowering of the water table caused by pumping

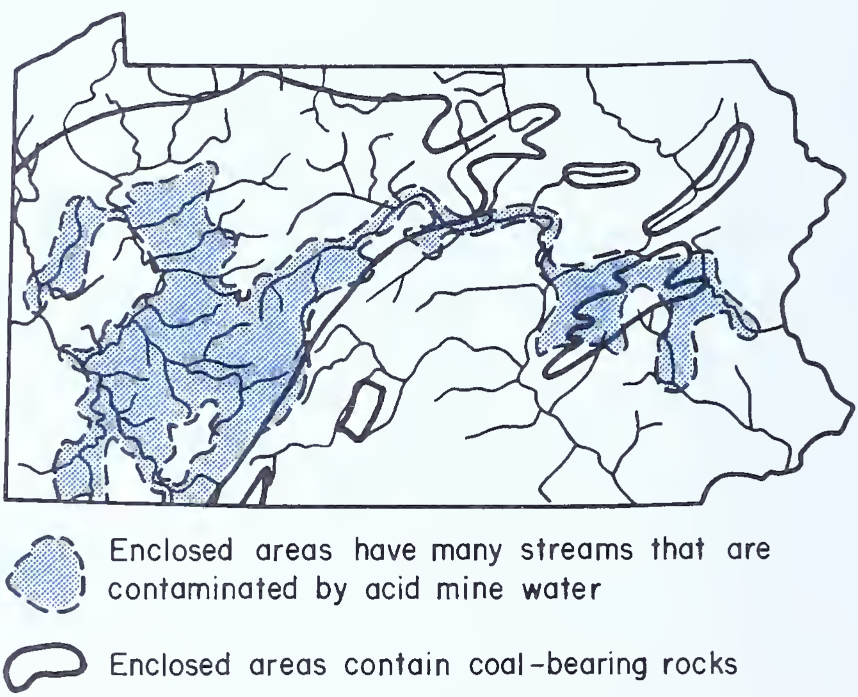
experienced declining ground-water levels because withdrawals of water exceeded the supply. The Lansdale-North Wales area in Montgomery County is an example. By the summer of 1954 water levels in Lansdale were as much as 140 feet below those in adjacent areas. Since 1954 a well southwest of Lansdale has had an average summer water level 26 feet below the 1954 level, suggesting a worsening condition. Since 1963, however, summer water levels in the same well have trended upward, indicating some improvement in conditions.

Problems of declining water levels because of excessive withdrawals may be alleviated by artificially recharging water into the aquifer through shafts, seepage pits, and wells, by inducing recharge from nearby streams, or by developing additional supplies from more remote sources.

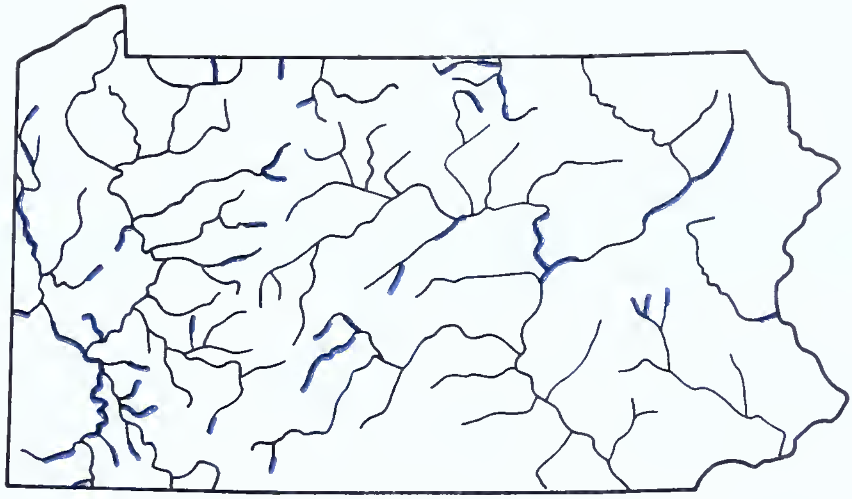
problems of quality

Both regional and local problems of water quality exist in Pennsylvania. Many of these problems are the result of activities undertaken in the past without adequately protecting our water resources.

Waters that flow from coal mines and contain high concentrations of sulfuric acid and iron in solution are the major problem of water quality both in the volume of water involved and the total area affected. About 2,500 miles of streams, in all three major river systems of the state, are contaminated by about one million tons of sulfuric acid that flows annually



Contamination by acid water from coal mines



Stream segments polluted by sewage and industrial wastes. Water quality below Sanitary Water Board standards.

Contamination by sewage and industrial water

from coal mines. Acid water is derived from precipitation that infiltrates surface strip mines and abandoned underground mines, dissolves iron sulfide minerals, and eventually flows out through shafts or other openings to the surface.

Second to acid mine waters in areal extent, but equally serious, is the pollution of Pennsylvania's stream and ground waters by sewage and industrial wastes. Stream pollution from these sources can be alleviated by putting adequate waste treatment facilities into service. The pollution of ground water is a more difficult problem because ground-water movement is very slow, and complete discharge of polluted water can take many years even after contamination has stopped. Therefore, prevention is the best practical cure for ground-water pollution.

The extent of ground-water pollution is much more difficult to determine than that of stream-water pollution. Bacterial pollution is one of the most dangerous types in ground water used for human consumption. Usually, the only wells and springs affected are those near places where human or animal wastes are concentrated, such as spetic tanks. Where this problem exists, it usually can be solved by chlorination. A more widespread form of pollution occurs when toxic or undesirable chemicals from industrial processes, landfills, or pesticides seep into the ground and are spread through the aquifer by natural movement of ground water. Some of the ground water in sand and gravel deposits in Philadelphia has become unusable because of the high iron content derived from many different sources, especially dumps and landfills.

Another type of ground-water pollution is caused by crude oil and saline waters moving upward into fresh water aquifers either through natural openings or through oil and gas wells abandoned prior to the well plugging law of 1951. The extent is probably not great, but pollution of this type is possible almost anywhere in Region 4. Saline water occurs naturally at depths as shallow as 300 to 500 feet below land surface in Region 4.

MANAGING OUR WATER

water rights

Water rights in Pennsylvania are not covered at this time by legislation, and controversies are often decided by the court based on case precedents and common law. Under common law the landowner has the right to reasonable use of all water in lakes and streams that touch his land, yet he does not own the water. In contrast, the landowner has absolute ownership rights to all ground water under his land. As common law does not recognize the close relationship between surface and ground water or other fundamental principles of water occurrence and movement, it does not provide a sound basis for assigning supplies and protecting investments. When demand begins to tax the available supplies heavily, or significant volumes of water become contaminated by man's activities, conflicts arise that are insoluble under common law. Controlled development can help prevent conflicts evolving from the overlapping rights to water that exist under common law.

development alternatives

In each area of Pennsylvania there are many alternative ways of developing the water resources. Each alternative will produce a different effect on the water and other resources of an area and of adjacent areas. For example, the development of large ground-water supplies may reduce the flow of a nearby stream by capturing water normally discharged into the stream by springs and may drain nearby swamps. Conversely, a reservoir will raise ground-water levels and may inundate land in upstream areas. Uncontrolled development could have unpredicted and sometimes unwanted effects on an area and may be unnecessarily expensive.

safe yield and management

Civil planners, water managers, and developers want to know the "maximum sustained yield" or "safe yield" of a region, aquifer, or stream basin. Any quantitative answer to this question depends not only on the natural water regimen but also on any changes caused by the effects of

existing development and the kinds of development that will be conducted in the future. For example, the development of a large ground-water supply may reduce the flow of a nearby stream below the rate needed to dilute sewage or industrial wastes adequately. If this effect cannot be tolerated then ground-water development would be limited to a production level that would maintain the required streamflow and the safe yield would be reduced accordingly.

Knowledgeable management of our water resources will help prevent water-development decisions that result in unwanted or intolerable effects or water-rights conflicts. Pennsylvania, in collaboration with adjacent states, has begun to manage its water resources through the establishment of river-basin commissions that have the authority to control development.

WHERE SHOULD WE USE GROUND WATER IN THE FUTURE?

The demand for water increases as our population, industry, and per capita need for water increase. More and more of our ground water will have to be developed to meet the demand. In some areas all available water eventually may have to be developed. It is most efficient, therefore, to develop the ground-water resources of areas that have excellent potential and leave surface water for downstream areas that have little potential. It is often possible to develop a ground-water supply more economically than a readily available surface-water supply.

The future development of Pennsylvania's ground-water resources will probably follow patterns similar to those of the past. Ground water will continue to be vital to the farmer and other rural dwellers. Industry will continue to require ground water to supply its growth needs and water utilities will require additional ground-water supplies to meet the demands of both industry and expanding residential communities.

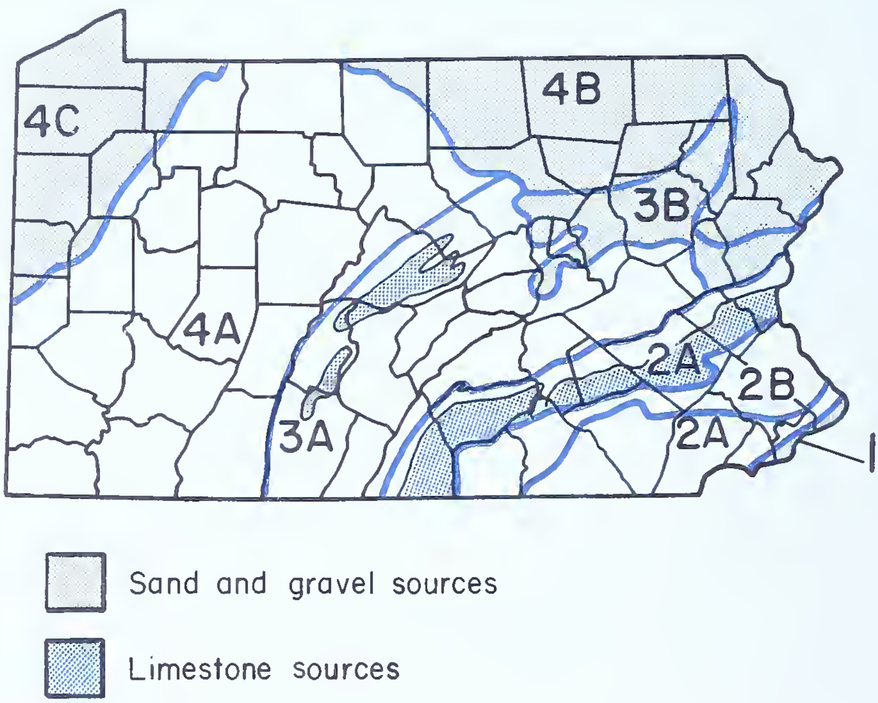
industrial supplies

Industry will probably develop more ground-water to supply both on-site expansion and new plants. Ground water is usually preferred by industry for cooling and product processing because of its constant, relatively low temperature, low cost, and sediment free nature. The locations of new plants are chosen because of their inherent advantages over other sites. For industries using large quantities of water the availability of an adequate supply is essential. Sites capable of supplying adequate ground-water supplies have a significant advantage over other sites. Excellent potential for large ground-water supplies exists both in developed and undeveloped areas in Pennsylvania. The sand and gravel

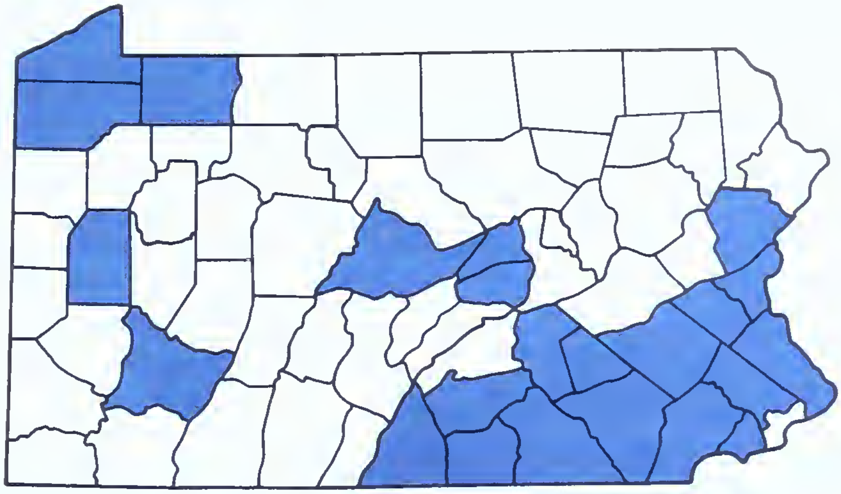
deposits in Region 1 and the limestone of Region 2 offer excellent potential for ground-water supplies in the more developed areas of our state. Limestones in the western part of Region 3A and glacially-derived sand and gravel deposits of Region 4C also are excellent ground-water sources in areas that are now beginning a period of extensive development. Glacial deposits of sand and gravel in the relatively undeveloped areas of Regions 3B and 4B have excellent ground-water potential. New and proposed highways are making the skilled labor forces and markets of nearby areas accessible to these regions.

small communities

Water utilities will probably continue to develop ground water for small and moderate-sized communities. Ground water is preferred for such use because initial development and later expansion costs generally are low and the only treatment usually needed is chlorination. Small older communities, distant from municipal distribution lines, may desire to change from multiple individually owned wells to a centrally supplied system to reduce costs or solve water quality problems. Ground water is ideal to supply these systems and can be developed almost anywhere in the state.



Major areas of Pennsylvania having potential for development of large ground-water supplies



Counties where major projected population increases may stimulate ground-water development

areas of projected growth

Rapid suburban growth beyond the limits or existing capacity of nearby city water systems has occurred in many areas of Pennsylvania in recent years. Such growth, in the form of residential developments, small communities, or moderate-sized towns, is increasing. Ground water can be developed in several ways to supply these communities. The most economical, usually, is the development of a community well or well field. Connection to a city system in the future could then be made at slight cost by using the existing distribution lines. Development of on-site privately owned wells may be less expensive or otherwise more desirable for some communities. However, if on-site privately owned sewage systems are also used, careful planning of the safe density and arrangement of units in both systems is necessary to prevent ground-water contamination.

The places most likely to develop ground-water supplies are adjacent to cities in areas of projected population growth. However, satellite communities may spring up near any city in the state or even at desirable sites quite distant from cities.

areas of poor quality surface water

The development of ground-water supplies may be the best alternative for public supply in cities as well as in smaller communities where streams are polluted. Large ground-water supplies may be available at

a cost much below that necessary to develop, maintain, or expand a surface-water supply that requires expensive treatment before it is fit to use.

auxiliary and emergency supplies

Some communities and cities have developed ground-water supplies that are kept in standby readiness. These supplies have many uses. A surface-water supply may be temporarily inadequate because of drought or an excessively warm period that stimulates demand above normal maximum capacity. Standby wells can also provide emergency supplies in the event a surface supply is temporarily contaminated by atomic fall-out or the upstream addition of toxic wastes.

SUMMARY

Pennsylvania has the ground-water resources to supply its growth needs in the foreseeable future. Local advance planning is needed, however, if we are to avoid water shortages, control pollution, and efficiently develop our ground water in conjunction with our other water resources. To provide the information needed for local planning requires a statewide continuing program of intensive ground-water investigations. Such a program is being conducted cooperatively by the Pennsylvania Topographic and Geologic Survey and the U.S. Geological Survey.

GLOSSARY

Acid mine water.—Water discharged from coal mines; commonly contains sulfuric acid formed by the solution of iron sulfide minerals by ground water.

Aquifer.—A rock unit or group of units that is capable of supplying water to wells in usable quantities.

Bedrock.—The solid rock of which the earth is composed; may be exposed at the surface of the earth or overlain by unconsolidated material.

BGD.—Billion gallons per day.

BGY.—Billion gallons per year.

CFS.—Cubic feet per second; a volume measure of water flowing past any point on a stream.

Crystalline rock.—A rock composed of interlocking mineral crystals in contrast to a rock composed of an aggregate of grains that have been cemented together.

Direct runoff.—Water that moves overland directly to streams after reaching land surface as precipitation.

Drawdown.—The lowering of water level in a well caused by pumping.

Fracture.—Breaks in rock caused by stresses.

Hardness.—A property of water, caused mostly by the presence of calcium and magnesium, which increases the amount of soap needed to produce a lather.

Ground water.—Water below the water table.

Limestone.—A rock composed chiefly of calcium and magnesium carbonates.

Public supply.—A water system providing water for general use to a community; in contrast to a private system that supplies a family residence, farm, or company.

Rock unit.—Any mass of bedrock or unconsolidated material that has been mapped as an entity and given a name; rock units have characteristic features that permit them to be separated from other rock units.

Ppm.—Parts per million; for practical purposes ppm is equivalent to milligrams per liter (mg/1); both terms are measures of the quantity by weight of dissolved mineral matter present in water.

Runoff.—That part of precipitation that appears in surface streams.

Safe yield.—The amount of water that can be withdrawn annually from a specified area without producing an undesired result.

Sand and gravel.—Loose aggregates of rock material composed mainly of sand and larger sized grains.

Sandstone.—Bedrock composed mainly of aggregates of sand-sized grains.

Shale.—Bedrock composed mainly of aggregates of particles smaller than can be distinguished with the naked eye.

Specific capacity.—The yield of a well divided by the drawdown necessary to produce this yield; expressed as gallons per minute per foot of drawdown.

Specific conductance.—A measure of the ability of water to conduct an electrical current; conductance increases with increasing concentration of dissolved minerals.

Stream basin.—The part of a landmass that is drained by a stream and all its tributaries.

Strip mines.—An open-cut mine in which material overlying the coal bed is removed before the coal is taken out.

Surface water.—Water on the surface of the earth.

Transpiration.—The process by which water vapor is released into the air, mostly through leaf pores, by plants.

Water table.—Below ground level, the upper surface of the zone that is water saturated; usually the underground continuation of lake and stream surfaces. It conforms in general with the land surface and is a subdued replica of that surface.

Well screen.—A slotted metal cylinder that permits the passage of water but prevents the entrance of sand and gravel into wells drilled in unconsolidated materials.

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W 5 *Ground water in south-central Pennsylvania* (1938).

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W 9 *Ground-water resources of Beaver County, Pennsylvania* (1951).

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W 18 *Hydrogeology of the carbonate rocks of the Lebanon Valley, Pennsylvania* (1963).

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agency sources of information and data about ground water

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